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BLACK SPRUCE IN THE FOOTHILLS OF ALBERTA

by

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Black Spruce in the Foothills of Alberta

INTRODUCTION

Black spruce is one of the most important trees in the boreal forest. It is a mainstay of the pulp and paper industry of eastern and central Canada and as such has received considerable attention from forest managers and silviculturists. This, however, has not been the case in the west, where black spruce has had little economic significance because of an undeveloped pulp industry. The recent establishment of a pulp mill in the foothills at Hinton, Alberta, and the expectation of more mills in the region now focus interest on the species.

Though black spruce ranks well below its associated coniferous species, white spruce and lodgepole pine, in the Alberta forestry scene it is nevertheless an important pulpwood resource in some districts. For example, in approximately 2,000 square miles of forest in the main study area (*see* Fig. 1), black spruce types occupy 15 per cent of the total area and black spruce comprises 9 per cent of the total merchantable cordwood volume.[1] The area contains as well a large amount of sub-merchantable black spruce. It should be borne in mind also that this is the most—and often the only—productive species on the bog sites which are frequent in the Lower Foothills.

The literature on the characteristics and yields of black spruce applies almost completely to regions east of Alberta. Much of it seems applicable to Alberta, particularly work done in adjoining Saskatchewan (Kabzems 1953) and Manitoba (Johnson 1956), in the B.18 or Mixedwoods Section of the Boreal Forest (Rowe 1959), which extends through much of Alberta as well. However, in the higher Foothills Sections (B.19) to the west, the differences in climate, physiography and vegetational associations which prevail in this transition zone between the Boreal and Subalpine Forest Regions suggested the possibility of variations in the performance of black spruce occurring there.

Thus in 1957 empirical studies of black spruce habitat-growth relationships and silvical characteristics were undertaken to enable comparisons with findings from other regions. The field work took the form of several specialized surveys in selected conditions. The conditions and procedures involved in each aspect are described together with the results, which are interpreted in the light of the relevant literature.

PART I

HABITAT RELATIONSHIPS[2]

Phytogeography

Black spruce ranges from Newfoundland to Alaska, extending in the west from the prairies and the main range of the Rockies north to the tundra. The present study was confined mainly to the foothills of Alberta, where the species ranges south to the Red Deer watershed. Most field work was concentrated in the Athabaska river watershed in areas representative of two divisions of the Foothills Section, the Lower Foothills (B.19a) and the Upper Foothills (B.19c) (Horton 1956, Rowe 1959).

[1]Figures supplied by North Western Pulp and Power Ltd.

[2]By K. W. Horton, Research Officer, Forest Research Branch, Ontario District Office, Richmond Hill, Ont.

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FIGURE 1

BLACK SPRUCE STUDY AREA
in
ALBERTA and SURROUNDING FOREST REGIONS

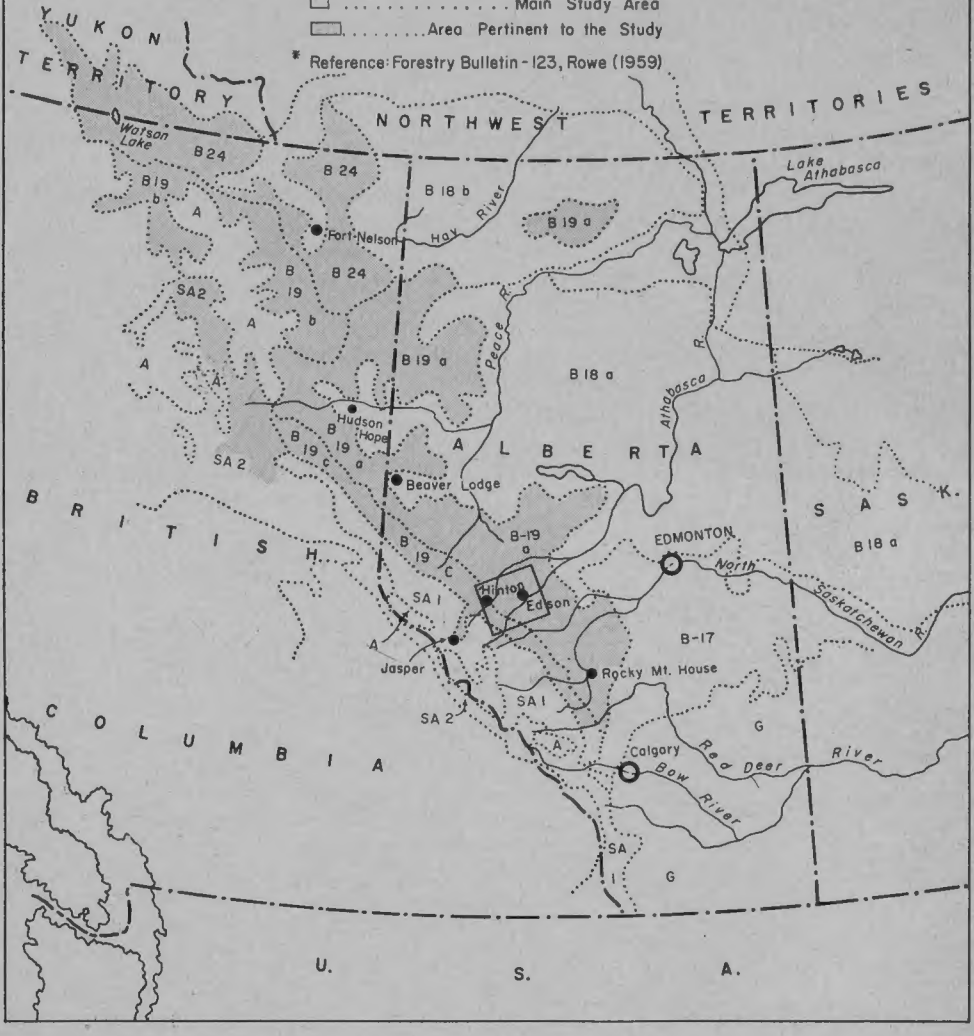
Scale: 1 inch = 175 miles

LEGEND

SECTION*	REGION*	SECTION*	REGION*
B 17	Aspen Grove	B 19c	High Foothills
B 18a	Mixedwood	B 24	Upper Liard
B 19a	Low Foothills	S A 1	Eastern Slope
B 19b	Northern Foothills	S A 2	Interior

A ..... Alpine
G ..... Grassland
☐ ..... Main Study Area
▭ ..... Area Pertinent to the Study

* Reference: Forestry Bulletin - 123, Rowe (1959)



The presence of lodgepole pine and alpine fir differentiates both foothills divisions from the adjoining B.18 or Mixedwoods Section of the Boreal Forest. Common to both are black and white spruce, aspen, balsam poplar, and tamarack. In the Lower Foothills the topography is moderately rolling and elevation ranges generally from 3,000 to 4,000 feet. Conditions closely resemble the B.18, with mixed forests of lodgepole pine, poplar and spruce prevailing on well-drained sites, and black spruce and tamarack in the frequent bogs.

Contrasting with this, the Upper Foothills, ranging from 4,000 to 6,000 feet, support a predominantly coniferous forest of pine and spruce, and the steeper terrain results in fewer bog sites. The prevalent forest type is lodgepole pine with a black or white spruce understorey.

Conditions similar to these extend into the lower mountain valleys of the region and across northeastern British Columbia into the Yukon Territory (*see* Fig. 1). This includes all the B.19 Sections, valleys in the northern SA.1 and SA.2 Regions and the B.24 Section as described by Raup (1945) and Rowe (1959). Throughout these various phytogeographic areas which are somewhat similar in range of altitude, physiography and climate, black spruce occurs together with lodgepole pine, white spruce and, more locally, alpine fir and poplar. These similarities suggest that many of the findings of this study, confined to the southern part, might apply to the whole area described. However, at present the lower foothills portion is of chief economic interest and it was here that detailed sampling was concentrated.

Climate

Averaged weather records from stations of the Meteorological Service of Canada, scattered throughout the region described, are presented in Table 1. The bulk of the field work was done in the Edson, Alberta area, but it can be seen that the climate to the north is reasonably similar though naturally cooler. In general, the climate is characterized by lower precipitation and somewhat cooler temperatures than are found eastward in Canada and Minnesota where most published data on black spruce growth originates.

Table 1

CLIMATIC RECORDS PERTINENT TO THE REGION

Station	Av. Ann. Precipit. (inches)	Av. Ann. Snowfall (inches)	Av. Ann. Mean Temp. (°F.)	Av. Jan. Mean Temp. (°F.)	Av. July Mean Temp. (°F.)
Watson Lake, Yukon	15.85	67.4	29	−4	58
Fort Nelson, B.C.	15.41	59.8	31	−5	62
Hudson Hope, B.C.	15.85	58.9	34	4	60
Beaverlodge, Alberta	17.19	70.1	35	6	60
Edson, Alberta	18.64	57.3	36	9	60
Rocky Mountain House, Alberta	19.13	55.7	34	6	58

Site Classification

Black spruce is generally considered a swamp tree, although it is recognized as a species of wide ecological amplitude, quite capable of growing on drier upland sites as well. Most workers have classified black spruce forest into at least two site types—swamp and upland. The former usually involves pure black spruce stands and the latter mixedwoods. Black spruce forms mixed stands with all of the common uplands species, white spruce, pine, poplar and birch. In some studies, notably Kabzems (1953) in Saskatchewan, a third site type, the swamp border type, has been recognized. It is obvious that drainage

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FIGURE 2. Mature black spruce in a shallow bog, Lower Foothills.

FIGURE 3. An immature lodgepole pine stand with a dense black spruce understorey. Upper Foothills upland site.

is a primary factor in the distribution of black spruce stands; competition from more vigorous species on upland sites usually relegates it, on a stand basis at least, to the wetter sites.

A comprehensive treatment of black spruce site relationships is available in MacLean and Bedell (1955) for the Clay Belt of Northern Ontario, where the species predominates on a wide range of sites. These authors used a site classification based on two physiographic features, moisture regime and permeability or pore pattern, recognized in Hills' (1952) system of site classification. This basic method was tested for the present study in the Lower Foothills and found applicable in simplified terms. Permeability in itself is not influential on the peaty wetter sites; on the moist transitional sites of this region, where heavy loams prevail, it was found to be fairly uniform. Thus it appeared possible to use moisture regime alone as a direct indicator of site quality for black spruce.

Moisture regime was determined by the soil profile, particularly the depth of humus, depth to the zone of gleization and to the water table. Detailed descriptions of the classified site types pertinent to black spruce are set out in Table 2.

The usual tree cover and the maximum black spruce height at 100 years encountered on each site are added for comparison. Further data on the black spruce growth differences on a stand basis according to site are provided in Part III of this report. A description of the recognized site types emphasizing practical black spruce relationships follows. Moisture regimes 4 and 5, being both transitional to the upland sites and minor on an area basis, were combined for simplification.

Mesic Upland—Moisture Regime 2-3

This is the "normal" (*vide* Hills 1952) forest site of the region, the upland conditions of optimum drainage and a well-developed soil profile in loams mostly of till origin. A distinct leached A_2 horizon, usually 1 to 2 inches deep, and marked B horizons of varying depth characterize the profile. The water table is well below three feet generally, beyond the reach of spruce roots. Black spruce rarely forms pure stands here but is frequently present as an understorey, together with white spruce, beneath pine and aspen (*see* Fig. 3). This applies particularly in the vicinity of bogs and drainage channels which often provide refugia for some black spruce seed-bearing trees from fire, the major influence behind the stand history of the region (Horton 1956).

Upland Transition—Moisture Regime 4-5

Usually this forms a narrow, gently sloping gradient between bog and upland. It is relatively unimportant on an area basis but it has a frequent occurrence and a relatively high productivity for black spruce. Being a transitional site, all species of the region commonly occur here in varying mixtures. Balsam poplar and white spruce seem to thrive particularly well on moisture regime 4, and on the wetter side, moisture regime 5, a common cover type is dense black spruce with scattered pine or white spruce emerging as an overstorey. Because of the normally dense canopy, the ground vegetation is dominated by feather mosses. Soil profile development ranges from moderate to negligible but there is practically always some trace of the leaching process. The presence of gleization at a depth of about one foot and a water table within two feet of the surface are distinguishing features of this site.

Bog Border—Moisture Regime 6

Most of the more productive pure black spruce stands of the region are found on this site. It often consists of a narrow gradient along with the Upland Transition, but sometimes occurs in broader patches. The cover is normally

Table 2

A BLACK SPRUCE SITE CLASSIFICATION FOR THE FOOTHILLS OF ALBERTA

Site Type	Moisture Regime	Slope (%)	Horizon Development Depth (inches) of			Glei Zone		Water Table Average Depth	Tree Composition		Maximum bS Height At 100 Yrs.
			A_0 A_1	A_2	B	Depth	Horizon		Major	Minor	
						(ft.)		(ft.)	−	+	(ft.)
Mesic Upland	2–3	Variable	2 Trace	Moderate	Strong	Over 3	Lower C	Over 3	lP−A+bS,wS		76
Upland Transition	4	5–10	2 to 5	Weak	Moderate to Weak	1–2	Upper C	2	wS−bS−lP−Po		74
	5		6 to 11	Trace − Nil		Under 1	B	1.5	bS+wS,lP,bP		
Bog-border	6	1–7	12 to 20	Nil	Nil		All mineral soil	1	bS+wS,tL,bP		69
Bog-shallow	7	0–4	21 to 36	"	"		"	0.5	bS+tL		53
Bog-deep	8	0	36+	"	"		"	0 (+humps)	bS−tL		45
Marsh	9	0	36+	"	"		"	0	Nil		

lP = lodgepole pine
A = aspen
bS = black spruce
wS = white spruce
bP = balsam poplar
tL = tamarack
Po = poplar

FIGURE 4. A mixed stand of poplar, pine and spruce spp. on the upland transition site.

FIGURE 5. A heavily stocked maturing black spruce stand on the bog border site. Note the emergent white spruce.

well-stocked black spruce with occasional white spruce, balsam poplar or tamarack. The ground vegetation includes some elements of both bog and upland but again the feather mosses prevail. A peat layer usually from 12 to 20 inches deep, saturated to within one foot of the surface at least part of the growing season, and overlying silt loam or clay loam glei, characterizes the site. Drainage is imperfect to poor.

Shallow Bog—Moisture Regime 7

This site is marginal in productivity. Merchantable black spruce stands can develop on it in a reasonable rotation age, but in many cases overstocking prevents it. Tamarack is often present in minor amounts and, rarely, white spruce. The distinguishing edaphic feature is an organic cap between two and three feet deep, saturated within one foot of the surface during the growing season. Frequently, humps composed of feather and bog mosses up to one or even two feet high develop above the general peat level on this site, and frost is sometimes present in the heart of these humps during the growing season.

Deep Bog—Moisture Regime 8

Individual black spruce of merchantable size may occur on this site, given enough time, but stocking is generally so inadequate that the site can be classed as unproductive. An admixture of irregular-aged tamarack usually occurs with the black spruce, and sometimes predominates. The peat layer here is more than three feet deep but the limiting factor is lack of drainage. It is saturated almost to the surface with stagnant water throughout the growing season except on the moss humps which are prevalent. If the water table were lowered it is likely that productivity comparable to that of moisture regime 7 would be obtained. An abundant ground flora of bog shrubs, herbs and mosses occurs on this site.

FIGURE 6. A marsh association and a black spruce bog site type (moisture regime 7–8) in the background.

Marsh—Moisture Regime 9

This site is added only to describe the extreme from which the other bog sites are graded. It has no commercial forestry value. The class may be applied to wetter phases of the deep bog in which saturation is even more complete, and moss humps fewer; here, scattered tamarack and occasional stunted black spruce may occur along with typical wet bog vegetation. More often, however, it is characterized by a sedge-wet moss community (*Carex-Drepanocladus*) and is devoid of trees.

Vegetation Associations

The lesser vegetation on each site is presented in Table 3, relative importance being indicated by constancy classes. Constancy refers to the percentage of natural spruce stands in which the species was found in a total sample of 116 stands. These percentages were grouped into 25 per cent level classes for convenient comparison between species and sites. The dominating species, those with an average area coverage of more than 25 per cent, are in boldface in Table 3. It is obvious that many of the commoner species are ubiquitous, occurring with minor variation in constancy over the whole site range. Others are limited to certain sites, usually either on the wet side or dry side of the scale, and these may vary widely in constancy, showing certain site preferences.

Table 3

LESSER VEGETATION ASSOCIATED WITH BLACK SPRUCE BY SITE IN THE LOWER FOOTHILLS

Species*	Constancy Class by Moisture Regime						
	2–3	4	5	6	7	8	9
Shrubs							
Ledum groenlandicum	B	A+	A	A+	**A+**	A+	B
Vaccinium vitis-idaca	B	A	B	A	A+	B	
V. oxycoccos					C		C
V. myrtilloides	C	C	C	C			
V. caespitosum	C	C					
Rosa acicularis	A+	A+	A+	A+	C		
Shepherdia canadensis	B	C	C				
Viburnum edule	C	B	C	C	C		
Lonicera glaucescens	C	C	C	C		C	
L. involucrata	B	A+	A	A	B		
Potentilla fruticosa			C	B			
Betula glandulosa				B	B	**A+**	**A+**
Ribes lacustre			C	C			
Salix myrtillifolia	C	B	B	A+	B	C	
S. candida and pedicellaris						A+	A+
Kalmia polifolia						C	B
Symphoricarpos alba	C		C				
Amelanchier sp	C	C					
Rubus chamaemorus					C		
Grasses, etc.							
Elymus innovatus	C	C	C				
Other grasses	B	B	C	C	B	C	
Carex leptalea		C	B	A+	B	A	A
C. aquatilis			C		C	**A+**	**A+**
C. vaginata		B	A	A+	B	B	
Juncus spp.				C		C	A
Equisetum scirpoides		C	A	A+	B		
E. arvense		C	B	A	A	B	
E. sylvaticum		C	C	C	C		
E. pratense		C	C	B			
Herbs							
Cornus canadensis	A+	A+	A+	B	C		
Linnaea borealis	A	A+	A+	A+	B	C	

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Table 3—Cont'd

LESSER VEGETATION ASSOCIATED WITH BLACK SPRUCE BY SITE IN THE LOWER FOOTHILLS—Concluded

Species*	Constancy Class by Moisture Regime						
	2-3	4	5	6	7	8	9
Herbs—Concluded							
Epilobium angustifolium	B	A+	A+	A	C		
Mitella nuda	C	B	A	B	A	C	
Mertensia paniculata	B	B	A	A			
Fragaria virginiana var. glauca	B	A	A	A	C		
Achillea borealis		B	B	A	B	C	C
Galium boreale	C	B	A	A+	C		
Petasites palmatus	A	A+	A+	A+	B		
P. sagittatus					C	C	C
Smilacina trifolia			C	B	A	A+	A
S. amplexicaulis	C			C			
Pedicularis groenlandicum							C
Orchis rotundifolia				C		B	
Habenaria obtusata		C	C				
H. hyperborea						C	C
Lathyrus ochroleucus	B	C	C	C			
Phaca americana		C	C				
Actaea rubra	B		C				
Geocaulon lividum	C		C	C	C		
Pyrola spp			C	C			
Arnica cordifolia		B					
Rubus acaulis					C	B	C
R. pubescens	B	B	B	C			
Geum macrophyllum				C	C		
Anemone parviflora			C			C	
Potentilla palustris					C	B	B
Caltha palustris						B	A
Menyanthes trifoliata						C	**A+**
Mosses							
Hylocomium splendens	**A+**	**A+**	**A+**	**A+**	**A**	A	C
Pleurozium schreberi	A+	A+	A+	A	**B**	B	C
Hypnum crista-castrensis	A+	**A+**	**A+**	**A**	B	C	
Dicranum spp	C	B	C	C	C		
Polytrichum spp		C			B		
Sphagnum spp				C	**A**	**A+**	A+
Aulacomnium palustre		C	C	A	A	A+	A+
Camptothecium nitens		C	B	A+	A	**A+**	**A+**
Mnium spp		C		C	C	B	
Drepanocladus spp				C	C	**A**	A+
Peltigera spp	A	A+	A	A	A	C	
Cladonia spp	C	B	B	B	B	C	

Constancy Class	Per cent Class
A+	75+
A	51+
B	26–50
C	1–25
Blank	0

Boldface letter = dominant species.

*Nomenclature as in "Forest Flora of Canada" (Cunningham 1958).

Thus there is a group of species which is confined to the wettest sites, moisture regimes 8 and 9, namely, *Kalmia polifolia, Salix candida, S. pedicellaris, Caltha palustris, Menyanthes trifoliata, Habenaria hyperborea,* and *Pedicularis groenlandicum.* An abundance of *Betula glandulosa, Carex aquatilis* and *Drepanocladus* also "indicates" these wet sites.

A few species, *Vaccinium oxycoccos, Rubus acaulis, Petasites sagittatus* and *Potentilla palustris* appear to range from the wet to the shallow bog but not into

the bog border. Conversely, the upland species *Rosa acicularis, Viburnum edule, Lonicera involucrata, Epilobium angustifolium, Fragaria virginiana, Geocaulon lividum* and *Dicranum* extend into the shallow bogs but not into wetter conditions. An adundance of *Sphagnum* characterizes all bog sites.

The bog border is the borderline of occurrence of the swamp species *Betula glandulosa* and *Sphagnum,* and of the upland species *Vaccinium myrtilloides, Mertensia paniculata, Lathyrus ochroleucus* and *Rubus pubescens.* It is also the borderline of high constancy of the swamp mosses *Aulacomnium palustre* and *Camptothecium nitens* and of the upland species *Pleurozium schreberi, Hypnum crista-castrensis, Rosa acicularis, Petasites palmatus, Linnaea borealis* and *Equisetum pratense.*

The upland transition site appears to be the limit of the upland species *Shepherdia canadensis, Symphoricarpos alba, Vaccinium caespitosum, Habenaria obtusata, Phaca americana, Actaea rubra, Arnica cordifolia,* and *Elymus innovatus;* and, on the other hand, of the swamp mosses *Aulacomnium, Camptothecium* and *Mnium,* the swamp herb *Smilacina trifolia,* and three *Carex* and *Equisetum* species.

The upland sites were not sampled adequately enough to carry this characterization further. It is evident that different groups of bog and upland species characterize the different site types as classified, and accordingly will assist in their identification.

Comparison of Lower and Upper Foothills

The above site type descriptions were developed for the Lower Foothills only. While many of the relationships apply as well to the Upper Foothills—the soil profile descriptions appear to be directly comparable—there are certain differences. Tamarack is infrequent in the upper areas, although scattered trees occur above the 4,500-foot level. Aspen is much less common and alpine fir more common in the Upper Foothills. There are several plants absent from the black spruce site types, including *Vaccinium oxycoccos, V. myrtilloides* and *Equisetum sylvaticum,* several much less common such as *Betula glandulosa, Rubus pubescens, Petasites palmatus* and *Sphagnum,* and a few more common, i.e., *Orchis rotundifolia, Habenaria obtusata, Geocaulon lividum, Anemone parviflora, Minum* and *Thuidium* mosses.

Some of these differences may be attributed to climate as it controls specific ranges. Another local factor is soil reaction (pH). In certain localities of the Upper Foothills, hangmoor conditions are common; these are caused by surface seepage on hillsides usually of moderate slope, forming moisture regimes ranging from 5 to 8. Where the bedrock is calcareous, a high concentration of lime is deposited in the soil profile, resulting in high soil pH levels, up to 8.0, sometimes even in the organic cap. Some bog species are definitely unsuited to such high pH's, but black spruce appeared to grow as well there as on the slightly acid bog conditions of the Lower Foothills where pH's of humus and mineral soil ranged from 5.5 to 7.0. There can be no general division of the Upper and Lower Foothills on the basis of high pH calcareous and low pH non-calcareous soil, for each has both. Strangely enough the most acid conditions (pH around 4.0) encountered under black spruce were in an old stand which had developed under lodgepole pine on moisture regime 2 at the top of a high foothill. No typical acid bogs were found in the Lower Foothills.

Natural Succession

The importance of fire in the history of black spruce throughout its range has been well established. In the foothills region practically all stands containing black spruce over the whole range of sites can be traced to fire origin. As a consequence, the stand structure is generally even-aged. The actual total age will

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vary only a few years from tree to tree if the canopy is complete; however, if the stocking is more open, continued reproduction of both seed and vegetative origin will result in a broader age range. Similarly in older stands where the canopy has been depleted by natural mortality or by light ground fires, an irregular age structure may occur.

Stand development will depend on site and accordingly on species competition. For wet sites, Moss (1955) has summarized successional relationships as they have been described in several botanical papers on Alberta bog development. The basic stage is aquatic and marsh vegetation formed in basins. The next stage may take two courses, developing into either a *Drepanocladus-Carex* bog or a wet *Sphagnum* bog, either of which constitutes our moisture regime 9. Following this, the former may evolve through bog willow and birch stages to a predominantly *Larix laricina* association, or it may join the latter and develop into a *Sphagnum-Ledum-Picea mariana* association, thence into a sub-climax black spruce-bog moss association; this is our deep bog of moisture regime 8. "When this bog forest is burned", Moss states, "there is retrogression to earlier stages of the bog sere." Repeated burning may produce an open bog association characterized by *Ledum*, *Polytrichum*, *Sphagnum*, *Cladonia* and *Vaccinium* spp., with scattered black spruce, white birch and willow. Figure 7 illustrates these points nicely.

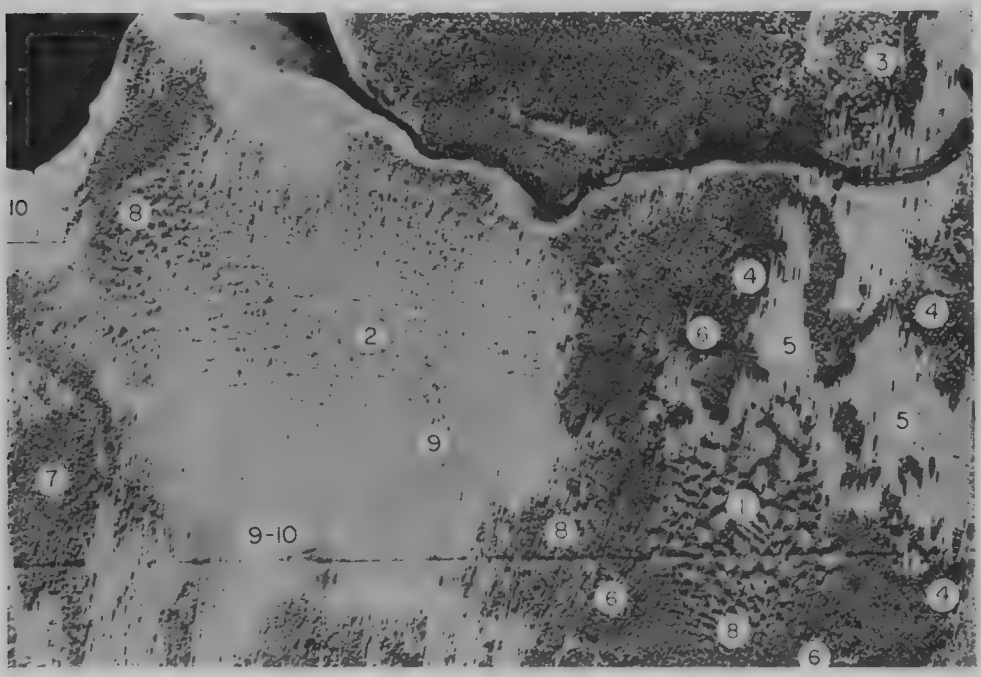

FIGURE 7

Air photo (scale 1″ = 660′) of a Lower Foothills boggy locality showing:

1. Polygonic pattern of black spruce growing on rigdes of bog moss, moisture regime 8, with intervening marsh areas of moisture regime 9 (*see* Fig. 8).
2. Bog Willow and bog birch stages with scattered tamarack, moisture regime 8–9.
3. Mesic upland site type—IP, tA, bS—moisture regime 3.
4. Upland Transition black spruce site type, moisture regime 5–4.
5. Open Bog of moisture regime 5–7, resulting from repeated burning.
6. Bog Border black spruce site type, moisture regime 6.
7. Shallow Bog black spruce site type, moisture regime 7.
8. Deep Bog black spruce site type, moisture regime 8.
9. Wet *Sphagnum* bog, moisture regime 9.
10. *Drepanocladus-Carex* Marsh, moisture regime 9.

For the shallower depressions and the slightly drained flats, Moss (1955) describes a black spruce-feather moss association which intergrades locally with a white spruce association and may contain poplar. It is interpreted as an edaphic climax maintained by poor drainage combined with periodic burning. This is comparable to our moisture regime 6 and possibly moisture regime 5. Moss suggests that the black spruce-bog moss association which develops through the bog sere will succeed to the black spruce-feather moss association barring fire, and this may apply in the flatter B.18 areas, but the present study suggests that in the foothills region the feather moss association is dominant only on moisture regimes 4–6. Our shallow bog site, moisture regime 7, provides a transition between the two associations recognized by Moss.

On upland and upland-transition sites black spruce is at a disadvantage, being slower-growing than all the common associated species. Normally it begins as an understorey in pioneer pine or aspen stands, its abundance determined by the availability of seed surviving the fire. It develops in height steadily but quite slowly, like white spruce. In fully stocked mature mixed stands, therefore, only a few black spruce will approach the general canopy level, most remaining more or less suppressed. Details of this competitive process are provided in Part II of this report under "Growth Patterns and Competition".

Provided fire does not occur, the upland stand will develop to a white spruce-black spruce and possibly alpine fir community, with the white spruce far outgrowing the black. However, fire generally *does* occur, preventing this succession. In fact, it may favour an increase in black spruce over white spruce in the next stand because of the former's serotinous cone characteristic which permits seed to survive fire in abundance. Also black spruce produces cones earlier than white spruce (Rowe 1955). Thus there are many upland stands where black spruce outnumbers white spruce as an understorey, particularly beneath pine. In restricted upper foothills localities a later development of such stands to

FIGURE 8. Black spruce distribution in a wet bog—a close-up of Feature 1 in Figure 7.

FIGURE 9. A dense black spruce-feather moss association on an upland transition site.

FIGURE 10. An early sub-climax black spruce stand succeeded from lodgepole pine on a High Foothills upland site. Note the pine deadfalls.

pure black spruce, an early sub-climax stage, was observed (Fig. 10). Presumably such well-stocked black spruce stands would break up with advancing overmaturity, permitting natural reproduction and thus tending toward an uneven-aged structure. Such was found to be the case in Minnesota (LeBarron 1948).

PART II

SILVICAL CHARACTERISTICS[3]

Seeding Habits

Cone Production

Black spruce begins to produce seed at about 15 years in Alberta, as it does in points eastward, and bears heavily and regularly from 50 years to past 150. Fairly abundant cone crops are frequent and complete failure is uncommon. The cones are semi-serotinous, remaining on the tree for some years. To determine how much these characteristics vary in the foothills conditions, the crowns of several dominant trees in different stands and sites were analyzed. All cones on a full half of each crown were categorized as to condition and age with the following results:

Table 4

CONE ANALYSES OF 7 BLACK SPRUCE TREES—ALBERTA FOOTHILLS

Tree No.	Age	Moisture Regime	Total No. of Cones	Per cent 3 years old or less	Per Cent of Total Cones					
					Wormy	Closed	Open	Under developed	Aborted	Bitten off
1	35	8	620	89	59	67	30	3	—	—
2	80	6	1036	79	31	71	17	1	1	10
3	80	6	1150	59	22	89	1	1	3	6
4	130	6	—	63	14	92	2	5	1	0
5	150	6	2700	16	44	27	51	17	5	0
6	80	3	3474	70	19	96	2	1	—	1
7	80	2	2578	91	39	49	31	19	—	1

As would be expected, there is a wide variation in cone production and conditions among the different trees. Tree number 5 had been uprooted some time before the cones were assessed, which may explain the high proportion of open cones. If that tree is omitted the average ratio of closed to open cones during the growing season is about 5 to 1. It is noteworthy that the trees with the most open cones also had the highest proportion of wormy cones.

The other cone condition categories are relatively unimportant in this sample. Since both the worm-damaged and the under-developed cones contained some viable seed, they cannot be ignored.

As to cone age, except in the oldest tree, number 5, most (60–90 per cent) of the cones were less than four years old. Of the older cones, most were open. Some were found remaining on the tree for up to 23 years, and in Manitoba, cones 39 years old are reported (Waldron 1957). However, viability of the seed decreases to zero after 15 or 20 years (Chai and Hansen 1952, Waldron 1957). Millar (1936), analyzing single cones in Ontario, found that less than 2 per cent of good seed remains at the end of three years.

[3] by K. W. Horton.

FIGURE 11. Standing fire-killed black spruce and lodgepole pine on an upland site.

FIGURE 12. Open and closed cones containing viable seed on a scorched black spruce crown.

Dissemination

The general result of these cone characteristics is a constantly present supply of seed which may be disseminated each year and to some extent at all seasons. Studies in Minnesota (LeBarron 1948) showed that only 57 per cent of the annual seedfall of 188,000 seeds per acre fell in the period from September to April.

It was found by the seed trap method in Minnesota that dispersal was effective only to a distance equal to two or three tree heights. That this also holds true in Alberta is indicated by Table 5, the result of a regeneration survey in a bog site burned 17 years previously. Sampling was done in groups of 20 milliacre plots set along lines at predetermined varying distances and directions from a residual black spruce seed source. Acceptable stocking of black spruce occurred only within two chains of the residual stand.

Table 5

DISTRIBUTION OF BLACK SPRUCE SEEDLINGS IN A BURNED DEEP BOG

Line No.	Direction from Residual bS	Distance in Chains from Residual bS	No. of bS per Milliacre	bS Stocking Per Cent
1	N	1	1.0	70
"	"	2	0	20
"	"	4	0	25
2	W	1	5.0	100
"	"	2	3.2	80
"	"	4	0.2	35
"	"	8	0	10
3	S	1	3.0	80
"	"	2	1.0	55
"	"	4	0	15
"	"	8	0	0

The semi-serotinous nature of black spruce cones permits a high survival rate of seed on standing fire-killed timber. In fact, the heat of a fire greatly increases subsequent seed dissemination by partially opening many closed cones. This was observed in a stand burned one year previously. Even slightly scorched semi-opened cones contained viable seed after one year in this case, and closed under-developed cones, protected by their position in the heart of the cone mass which usually is present at the top two or three feet of the tree, contained seed of which 10 per cent were germinated artificially. Thus an abundant seed supply is probably available from the brulé for several years, ensuring complete re-stocking, and often overstocking. This is the usual origin of our even-aged black spruce stands.

Reproduction

Vegetative Propagation

This species is unique among the spruces in its capacity for vegetative reproduction as well as in its serotinous cone characteristic. Layering, the formation of new stems by the rooting of the lowest whorl of branches in the moss or duff, has long been recognized as common. In the opinion of some it is the usual source of black spruce reproduction in swamps (Gates 1938, Bellefeuille 1935, Kenety 1917), although others have found seedlings outnumbering layers (LeBarron 1948, Place 1950, Johnson 1956). Their relative abundance will, of course, depend on how the local conditions favour each type of propagation.

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Layering is related to density as it effects self-pruning; hence layers are common only in more open stands, particularly where moss or duff build-up is fast enough to cover the lower branches.

Another mode of black spruce vegetative reproduction called "rooting" has been reported in Quebec (LeBlanc 1954). The rootings or "rootlings" as they have been termed, are simply roots or root sprouts which shoot upwards, forming a vegetative stem which is characterized by a short bushy crown of poor growth and seeding qualities. Suspicion has arisen that rooting may be much more common than is realized and has often been confused with layering. This is apparently the case in Alberta.

In figure 13 is a clear comparison of the two vegetative forms. This is a composite presentation of three, actual, excavated reproduction systems, with the most pertinent representative detail included. Obviously the situation can become very complex as rootings and layers develop from the same parent and may themselves form more rootings and layers. Moreover, seedlings and branches which have turned up to form new stems may add to the complexity. An example of the relative abundance of layering and rooting as opposed to seedling incidence in one area with varying site may be seen in Table 6, which also contains a comparison of relative annual height growth. It is evident that the performance of both forms of vegetative reproduction is far inferior to that of seedlings on all but the poorest seedbed media. Layers and rootings combined to form 25 to 60 per cent of the total reproduction, varying with site, and the proportion of rootings was much greater on all but the driest site.

Seedbed Preferences and Performances

Table 6 resulted from a regeneration survey of a 30-year-old burn in the Lower Foothills using Candy's (1951) method of groups of 20 milliacre quadrats laid out systematically. In this stand 820 quadrats on moisture regimes 3 to 8 were assessed as to species present, with the tallest representative of each species tallied. On 164 of the quadrats all the trees present were tallied and all the black spruce seedlings and saplings were uprooted to determine, if possible, their origin and seedbed as well as age and height. Specimens of questionable origin were rejected. The height data are presented in Table 6, while the stocking figures comprise Table 7.

As to seedbed preferences, dead wood was prominent; an average of some 40 per cent of the seedlings on all sites were rooted in or alongside wood litter. Seedbeds burned to mineral soil accounted for about one-quarter of the reproduction on the drier sites. Deep moss or duff was an important seedbed only in the bogs and particularly on the wet mosses where *Sphagnum* species predominated.

A further comparison of moss and mineral soil seedbeds for black spruce appears in Table 8. This applies to a burn one year old, a condition in which no dead wood was yet available as a seedbed and vegetative reproduction had not yet evolved. Again, there was a transition from mineral soil as the favoured medium on the upland site to moss in the bog sites.

In terms of height growth the mineral soil proved to be definitely superior, the average annual growth of all seedlings being twice as good as on the next best medium, rotten wood.

These reproduction tendencies in general corroborate findings elsewhere. LeBarron (1948) in Minnesota and Johnson (1956) in Manitoba found mineral soil best and undisturbed humus poorest for germination and early survival. Scarification in open conditions produced good black spruce regeneration in Quebec, particularly where Polytrichum mosses colonized the exposed mineral soil (Linteau 1957). Rotten wood generally provides a fair seedbed but is poor

Figure 13

Types of Vegetative Reproduction in Black Spruce

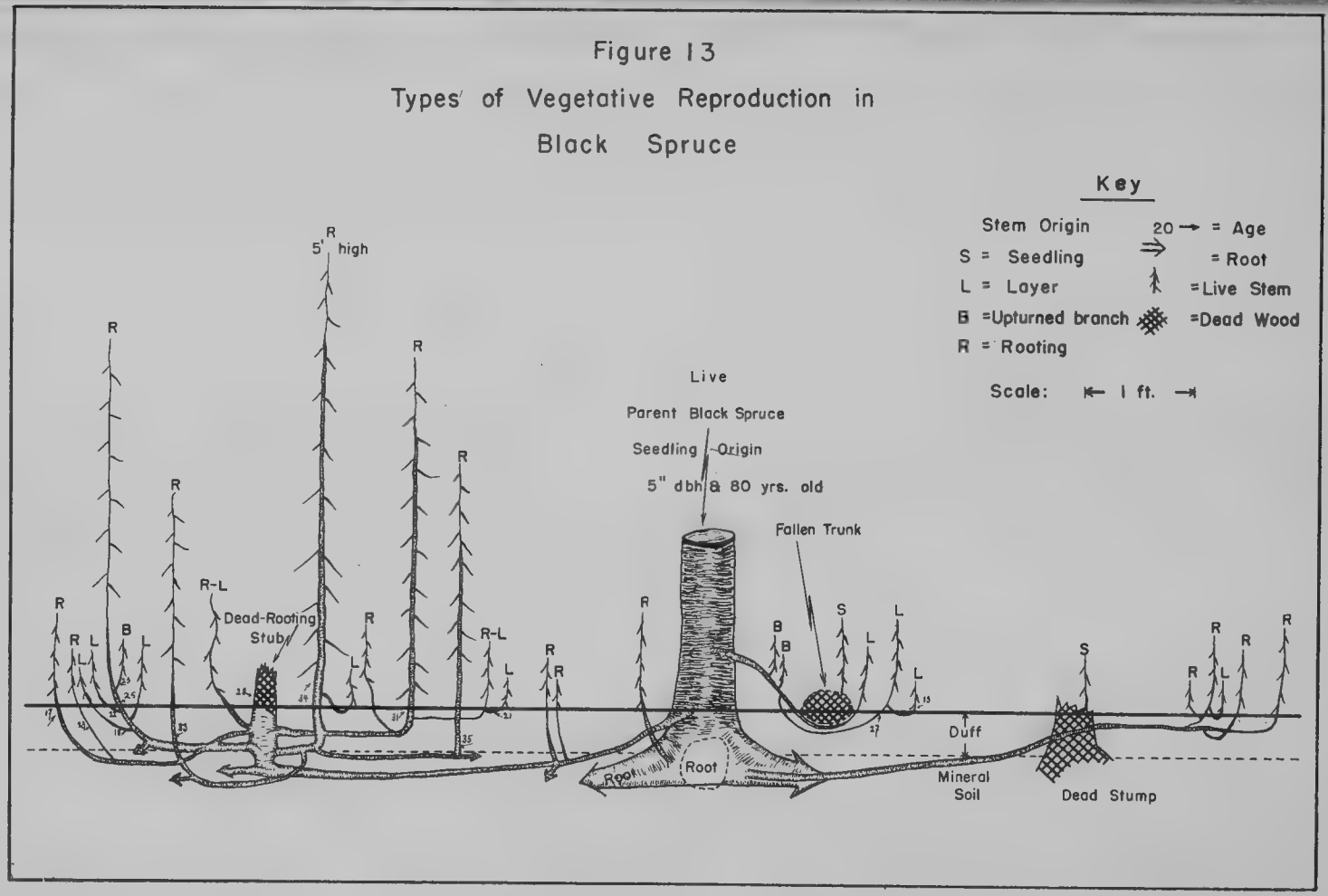


Table 6

BLACK SPRUCE REPRODUCTION—ORIGIN, SEEDBED PREFERENCES AND PERFORMANCES IN A 30-YEAR-OLD BURN IN THE LOWER FOOTHILLS

Moisture Regime	No. of Trees Sampled	Origin—Relative Per Cent					Average Annual Height Growth in Inches					
		Seedling Seedbed			Vegetative		Seedling Seedbed			Vegetative		
		Moss Duff	Mineral Soil	Rotten Wood	Layer	Rooting	Moss Duff	Mineral Soil	Rotten Wood	Layer	Rooting	Unknown Origin
3	120	1	26	36	12	25	—	5.6	3.0	1.2	1.4	3.1
4–5	260	5	26	42	6	21	2.2	4.8	2.5	0.9	1.6	2.9
6	307	1	5	30	6	58	—	6.8	3.3	0.9	1.7	2.1
7	240	25	—	40	5	30	1.4	—	2.7	0.9	1.7	2.1
8	72	28	—	46	6	20	1.1	—	1.6	0.9	0.9	1.6

Table 7

STOCKING OF BLACK SPRUCE AND ASSOCIATED SPECIES BY SITE IN A 30-YEAR-OLD BURN IN THE LOWER FOOTHILLS

Moisture Regime	No. of bS Per Acre	Per Cent of Milliacre Plots Stocked by Species				
		bS	tL	lP	tA	bP
3	3850	86	6	48	33	27
4	7750	90	14	31	27	23
5	5700	91	23	6	20	30
6	8250	85	30	3	—	1
7	6650	93	50	—	—	—
8	3000	69	58	—	—	—

Table 8

BLACK SPRUCE REGENERATION IN A ONE-YEAR-OLD BURN

Moisture Regime	Stocking Per Cent	Seedbed Origin Relative Per Cent	
		Moss Duff	Mineral Soil
3	37	—	100
5	85	58	42
6	95	100	—
7	85	100	—

FIGURE 14. A young stand of fire origin on an upland site. Lodgepole pine with a dense black spruce understorey.

from the growth standpoint. As to mosses, a feather moss mat is unanimously considered a poor seedbed, whereas Sphagnum is a good germination medium because of its constant moistness. However, some Sphagnum species grow so fast that they smother the tiny spruce seedlings (LeBarron 1948, Roe 1949). Details of the succession among the *Sphagna* leading from wet through intermediate stages to a static and relatively xeric condition involving *Sphagnum fuscum* and the feather mosses are given in Moss (1955) for Alberta. It is evident from this description that black spruce germination would be most prevalent in the intermediate stages, involving *Sphagnum magellanicum* and others.

Stocking

Burned Areas—The adaptability of black spruce to a variety of seedbed conditions, combined with the vegetative reproduction tendencies, generally result in successful restocking of burned areas. As Table 8 shows, stocking on a milliacre basis may be adequate on the moist sites as soon as one year after the fire. Stocking might not be so successful at this stage in a hot dry year, when the blackened surfaces reach lethal temperatures (LeBarron 1948, Place 1949). By 30 years, as in Table 7, the species may be fully represented over the whole site range of a locality, competing with various species on the different sites. It is not always as well distributed on upland sites as Table 7 might suggest, but on the productive bog sites overstocking is more the rule than the exception.

Mature Stands—The tendency towards high densities means that natural reproduction has little chance for development in undisturbed mature stands. A tally of reproduction was made on all the undisturbed yield study plots used in Part III of this report, involving altogether some 2,400 milliacre quadrats. Stocking of black spruce under 2 feet high averaged 3 per cent on moisture regime 4–5, 6 per cent on moisture regime 6, and 16 per cent on moisture regime 7—insignificant, all told. Cotyledonous seedlings were not included in this estimate and they were observed to be fairly numerous in some conditions, particularly on wet moss seedbeds; however, they rarely survive, as the lack of appreciable present advance growth testified. In a few open black spruce stands that were observed, advance growth of vegetative origin was fairly common.

Cut-over Areas –Until recently there have been virtually no cutting operations in Alberta's black spruce stands. In some upland sites, however, partial cutting of lodgepole pine and white spruce growing with black spruce has occurred, providing some idea of the regeneration potential of black spruce in cut-over conditions. The stocking on 280 milliacre plots in such conditions averaged 10 per cent, of which 8 per cent was advance growth. There was plenty of seed available from the residual trees, which also provided a reasonable degree of shelter. Moreover, there was seed contained in cones on some two-year-old black spruce slash, which proved to be 30 per cent viable. This poor reproduction is therefore largely attributed to an unfavourably dry feather moss and litter seedbed, a conclusion which Johnson (1956) came to in Manitoba.

No examples of reproduction following cutting in bog sites were available, but Heinselman (1957) cites several examples of successful regeneration on large clear cuts in swamp conditions in the Lake States, and Berry and Farrar (1956) found that both partial and clear cutting gave good regeneration results in an Ontario bog.

Tree Development

Root Forms

There is a dearth of concrete information on the rooting habits of black spruce, particularly for upland sites, although a superficial plate-like root form is considered generally characteristic on all sites. The deepest penetration of live roots in peat reported in the literature is two feet (Kenety 1917, Millar 1936).

However, it is not always a case of penetration, for adventitious roots may develop above the root collar in response to increasing moss growth (Heinselman 1957). Normally there is no taproot formation, but Millar (1936) found that some primary lateral roots turned downwards at their extremities and from them, secondary sinkers may descend for one or two feet.

Even in a mineral soil rooting medium there is little vertical penetration; Bannan (1940) found that it averaged only 3.5 inches for 15-year-old trees growing in coarse sand. This was found to be the case in the present study for black spruce growing in a loamy upland site. Though a rudimentary taproot was formed initially in some cases, its development was not maintained.

Several mature black spruce root systems were excavated in this study and the pertinent data are contained in the following figures.

Figure 15 illustrates typical examples of the two major vertical root forms, the shallow plate-like form rooted in the peat of the bog and transitional sites, and the rudimentary taproot form of well-drained mineral soil. It is obvious that both forms would provide poor anchorage compared with the normally deeper-rooted associated species. The reliance for anchorage must be placed on the lateral roots. Those of the tree on the upland site were very long, extending as far as 30 feet from the bole. The laterals of the bog specimen were interwoven with those of neighbouring trees. Where, as often happens in bogs, the trees are clumped, such root interweaving and natural grafting as is illustrated in Figure 16 would provide a great deal of added stability. Also, as LeBarron (1948) has pointed out, the resilience of peat would allow considerable root play and thus offset the chance of windthrow in disturbed stands.

This clumped effect has other implications. In Figure 17 there is an interesting example of the restriction of rooting and hence distribution of black spruce in a very wet bog. There is a marked proclivity of the roots for the somewhat drier bog moss mounds, and practically no distribution of active roots in the intervening wetter flats. Thus the available rooting area is much less than the total surface area, resulting in excessive density for the site capacity, hence poor growth. Examples of this tendency were also found to a lesser degree on drier bogs and may explain poor stand growth in cases where the number of trees per acre does not appear to be excessive.

Black spruce rooting at maturity may decline markedly under adverse conditions such as in deep bogs. In one dominant 100-year-old tree examined, over half of the main lateral feeder roots were dead and the majority of healthy roots were confined to mounds and dead wood. The high root mortality was reflected in loss of stem vigour.

Seasonal Leader Growth

The height growing period of black spruce appears to be considerably shorter in the foothills than in eastward regions. In the Lake States it commences in the first half of June and is completed by late August (Heinselman 1957). In Maine, a similar three-month period is involved but it occurs a week or two earlier (Baldwin 1931).

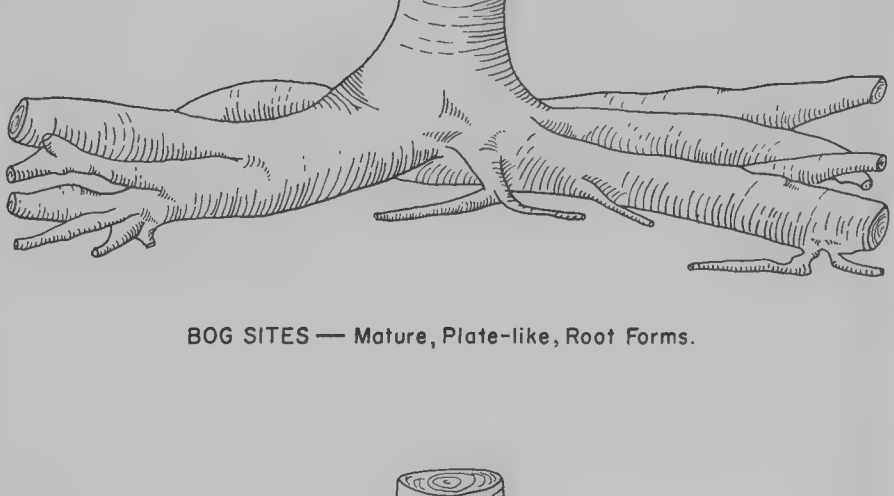
For comparison the weekly leader growth of ten 25-year-old black spruce was followed during the 1957 growing season. Only open-grown trees were chosen, to eliminate the effect of competition. To compare site effects, five trees growing on an upland site and five on a bog were selected.

Height growth in general began about June 1, was greatest during the first two weeks of July and ceased by August 2 -practically a month shorter than the cited cases. No difference was apparent between the trends on the two contrasting sites. Of the ten trees observed, four proved to have aborted terminal buds, and upturned laterals took over as shoots in each case. Such instances

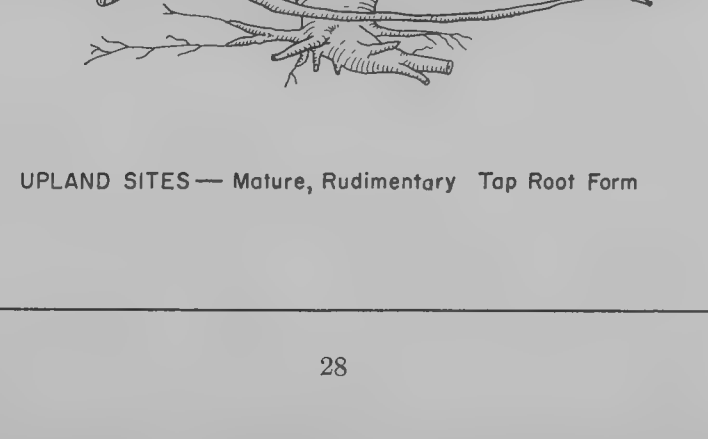
FIGURE 15

TYPICAL BLACK SPRUCE VERTICAL ROOT FORMS

Scale ←1 foot→



BOG SITES — Mature, Plate-like, Root Forms.



UPLAND SITES — Mature, Rudimentary Tap Root Form

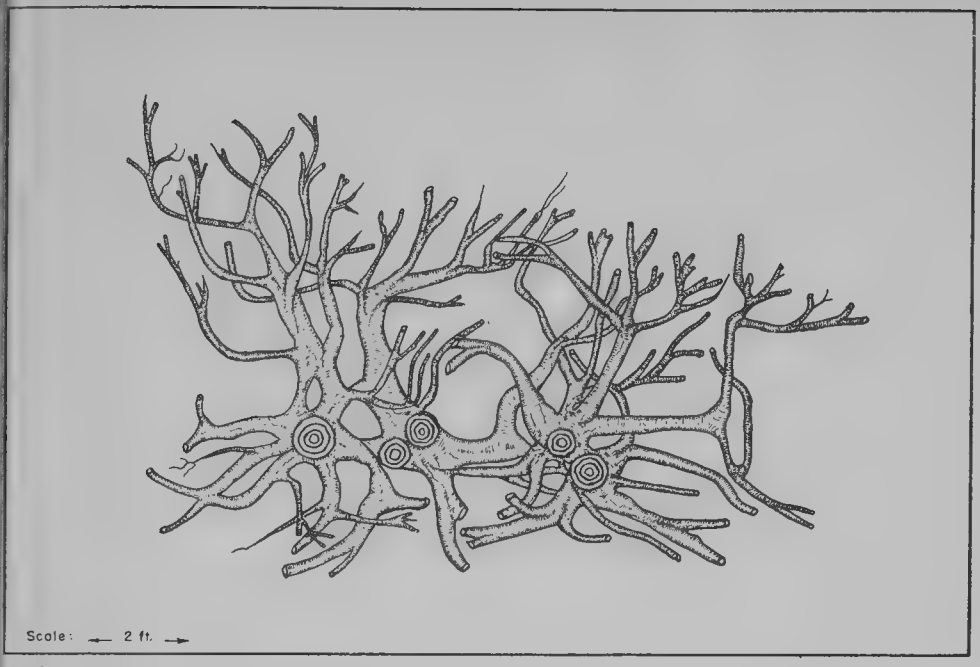


FIGURE 16. Plan view of interwoven lateral root systems of a clump of black spruce on moisture regime 6.

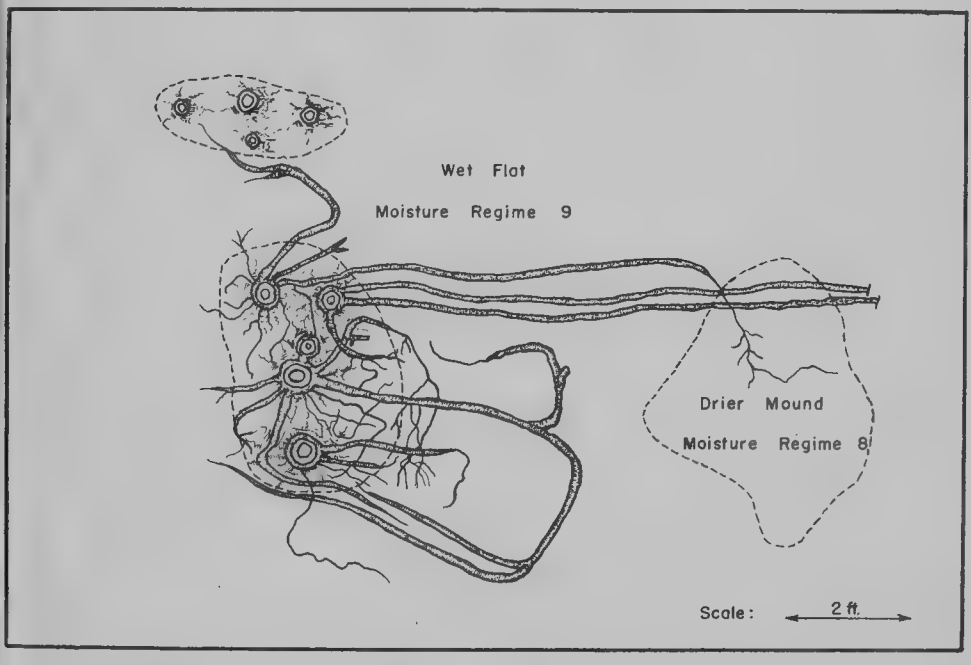


FIGURE 17. Plan view of black spruce root systems growing in a wet bog. Note the restriction of roots to the drier mounds.

were generally observed to be common in the region, and usually, though not always, resulted in decreased seasonal height growth. Clipping of branch tips by squirrels has a similar effect, and is one of the reasons for the ragged appearance of many crowns.

Early Height Growth

Table 9 shows the number of years required for dominant trees, regardless of seedbed, and for the average of all trees (curved values) to reach the critical heights for age determination of one foot (stump height) and 4.5 feet (breast height). As would be expected, there is a slightly slower growth on the less fertile bog sites.

Even at this early stage, it was observed, black spruce falls behind all of its associates except white spruce. On the upland sites, pine and particularly the poplars far outstrip it, although, provided ample spacing, individual black spruce trees may keep up with them. In the bogs tamarack shows slightly faster growth.

Table 9

AVERAGE NUMBER OF YEARS FOR BLACK SPRUCE TO REACH CRITICAL HEIGHTS

Moisture Regime	Dominant Trees Stump Height	Breast Height	Average Trees Stump Height
3	6	15	9
4	6	15	8.5
5	6	15	9
6	6	16	8
7	7	17	10
8	8	18	10.5

Growth Patterns and Competition

This section deals with the development of the individual black spruce and its relationship with competing species. For details of black spruce growth on a stand basis, the reader is referred to Part III.

Black spruce is a slow-growing species compared with its major associates. Even in its so-called "optimum" range from Quebec to Saskatchewan, the largest trees in average mature stands approximate only 9 inches d.b.h. and 65 feet in height (Heinselman 1957). The maximum dimensions recorded are in the Clay Belt of Ontario at 18 inches d.b.h. and 90 feet in height (MacLean and Bedell 1955). LeBarron (1948) reports slightly lower maxima of 17 inches d.b.h. and 85 feet high for Minnesota. The biggest single trees found during the present study were 15 inches d.b.h. and 80 feet tall, but the usual maximum size was 8–10 inches and 50–60 feet high. This growth applies generally throughout the Alberta portion of the region examined, in the Lower and Upper Foothills, in the lower mountain valleys and in the adjoining boreal plains.

To compare the life-time performance of black spruce in relation to that of competing species and in accordance with site, numerous stem analyses were carried out. First, typical stands in the Lower Foothills occurring on typical examples of each moisture regime were selected. The selection depended on a fully stocked condition, including, as well as black spruce, the various species normally occurring on the particular site. Then, dominant trees of each species were cut down and stem-analysed at five-foot intervals. Resulting height over age trends of the dominant trees in selected examples are presented in Figure 18.

FIGURE 18

HEIGHT DEVELOPMENT OF SELECTED DOMINANT BLACK SPRUCE and ASSOCIATED SPECIES ACCORDING TO SITE

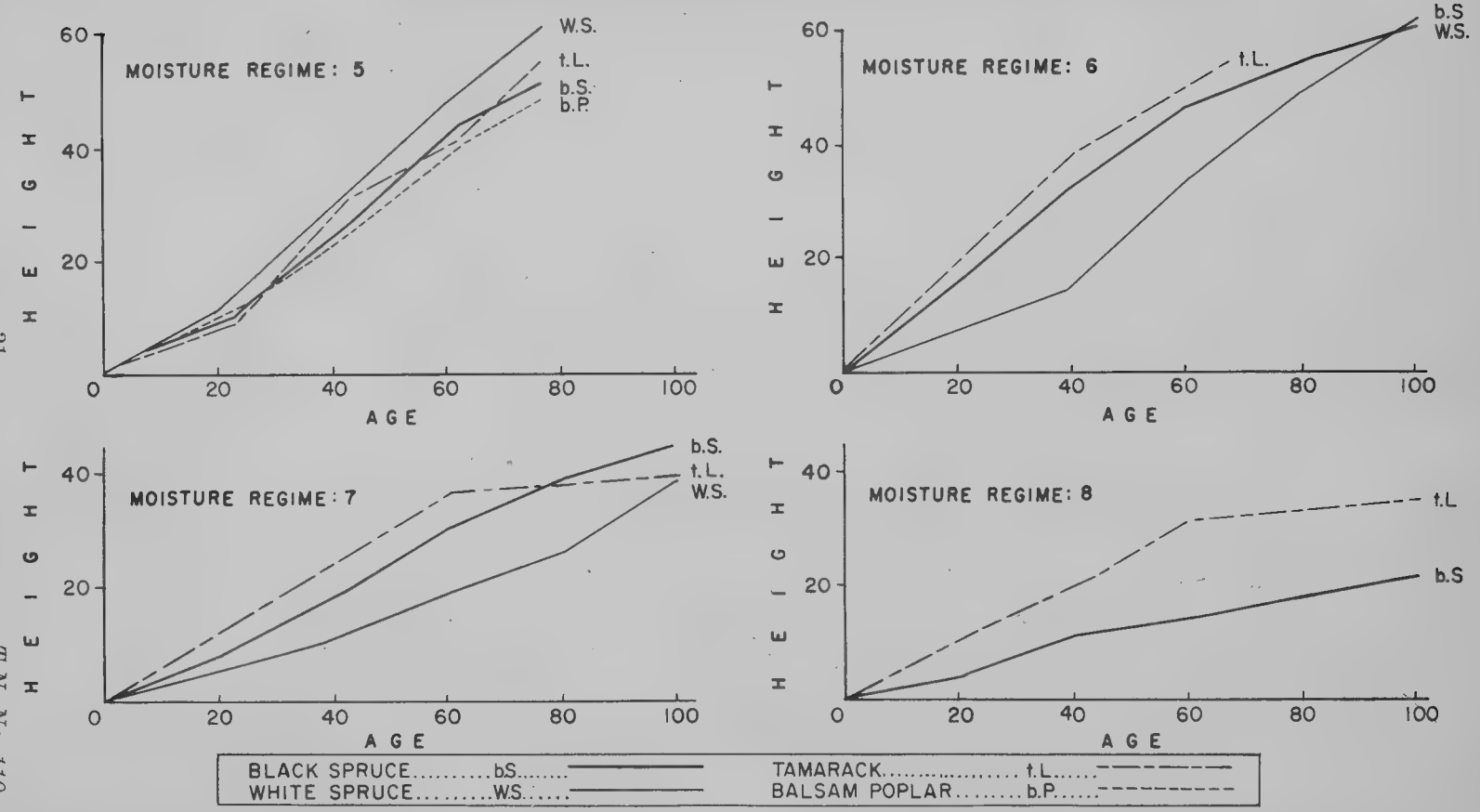
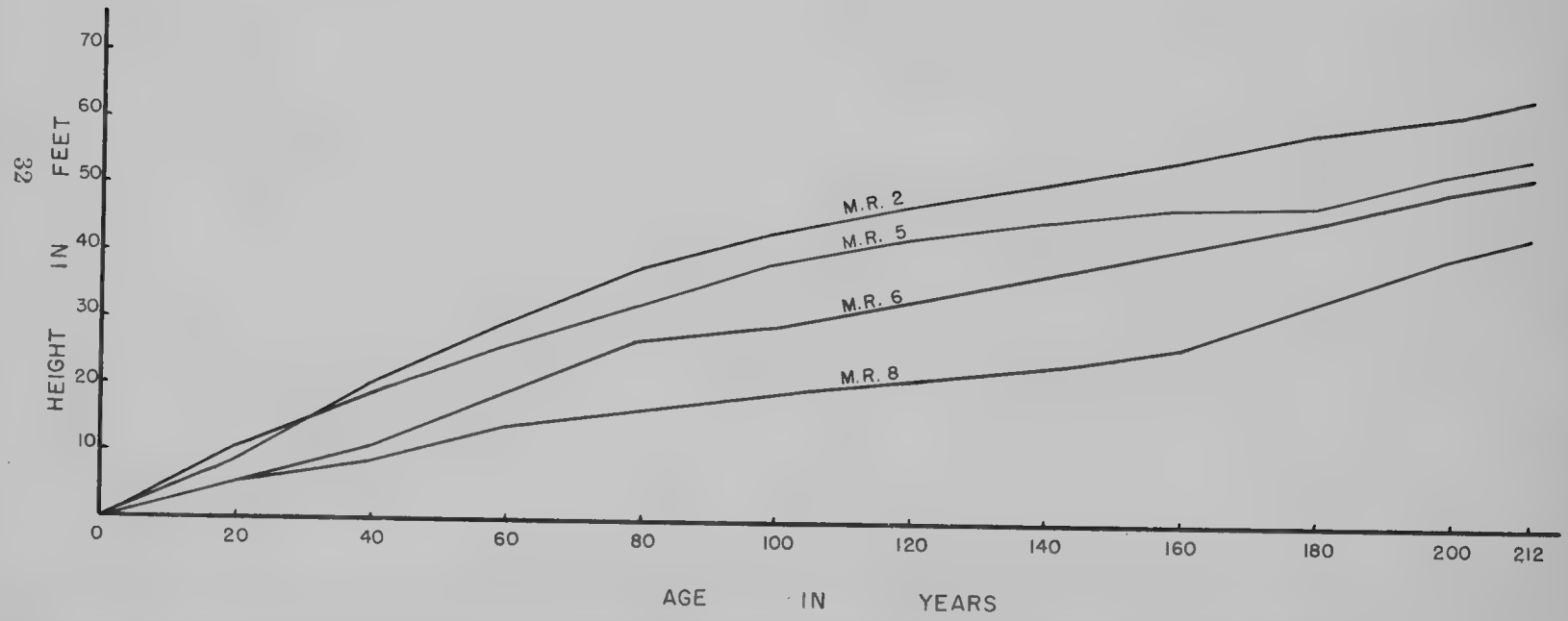


Figure 19

Samples of Height Development of Overmature Black Spruce by Site in the High Foothills



The overall picture unfolds. Virtually throughout their life span black spruce trees are outgrown by associated species on all sites. On the upland sites the pioneering pine and aspen retain their early height advantage to rotation age. At a later date, it was observed in the higher areas, white spruce and alpine fir dominate black spruce when the three are associated (Horton 1956). On sites of moisture regime 5, white spruce dominated after the young stage and tamarack showed a better performance than black spruce. Even on the sites which are most important commercially for black spruce in the region, moisture regimes 6 and 7, it was surpassed in height growth by tamarack and, later, by white spruce. Tamarack again proved superior on the wettest site, moisture regime 8, although eventually, after some 200 years, the dominant black spruce caught up to it.

The last point is noteworthy. Although in vigorous dominant black spruces the height growth curve tends to level off at advanced ages, in suppressed specimens there is a uniform height increase long past maturity. This is illustrated in Figure 19 by overmature co-dominants which had developed under pine or white spruce on a variety of sites in an Upper Foothills subclimax stand. Thus, at an advanced age after long suppression black spruce begins to compete in total height with the other species whose height growth has stagnated. However, white spruce, which has a similar steady height increment trend yet better growth after the immature stage, will dominate black spruce progressively in later years.

Longevity and Succession

The maximum longevity recorded for black spruce was 200–250 years on upland sites in the Upper Foothills (Horton 1956) and 270 years in wet bog of the Lower Foothills. Thus it can succeed poplar and pine on the uplands, and occasional examples of a black spruce sub-climax association may be found (*see* Fig. 10). If, however, the longer-lived white spruce is present, stiff competition is provided for black spruce in the overmature stages. The original black spruce will die off soon after 200 years, leaving scattered reproduction, mainly of vegetative origin, clumped around them.

Tamarack has been periodically subjected to larch sawfly infestations, and has rarely reached advanced ages, although scattered specimens over 300 years of age were found in some wet bogs. Because of this disturbance there is no valid basis on which to compare tamarack and black spruce successionally. Tamarack, like spruce, can reproduce abundantly by root sprouting (Beeftink 1951) but it is unquestionably less shade tolerant. These questions of succession can, however, be considered academic because of the frequency of fire in the past and, in all probability, cutting in the future.

PART III

GROWTH AND YIELD[4]

A survey was carried out to obtain sufficient information on growth and yield of black spruce in the foothills region of Alberta for the preparation of interim yield tables. Comparison is made with existing yield tables of Saskatchewan (Kabzems 1956), and Ontario (Bedell, MacLean and Brown 1955; Plonski 1956), to determine whether one of these tables could be applied, with some adjustment, to the Alberta stands.

[4]by J. C. Lees, Research Officer, Forest Research Branch, Department of Forestry, Alberta District Office, Calgary, Alberta.

Sampling Method

In order to obtain sufficient data for comparison, a cross-sectional sample of stands was designed in the main study area, described in Part I of this report, and mapped in Figure 1. A series of ten plots per age class on the dominant physiographic site, moisture regime 6, and a series of ten plots per physiographic site in the dominant age class were planned (Table 10). Plot size was adjusted to the density of the stand measured. Thus, 124 circular 1/5 and 1/10 acre plots were located in even-aged stands of consistent density, physiographic site and cover type. The plots were delineated subjectively in average, well-stocked stands, and height, diameter and age data were collected. All stems were tallied and 15 dominant and co-dominant black spruce per plot were measured for height/age relationships. However, lack of suitable stands below the 80-year age-class and the limited distribution of sample plots on some of the physiographic sites precluded a full cross-section. Scrutiny of the plot data indicated 101 plots suitable for compilation (Table 11).

Table 10

PLANNED DISTRIBUTION OF SAMPLE PLOTS BY AGE AND SITE TYPES

Age Class	Physiographic Site Types					
	2	3	4	5	6	7
0–20						
21–40						
41–60					60 plots	
61–80						
81–100	70 plots					
101–120						

Table 11

ACTUAL YIELD PLOT DISTRIBUTION BY AGE AND SITE TYPES

Age Class	Physiographic Site Types						Total
	2	3	4	5	6	7	
0–20							
21–40		1			6		7
41–60							
61–80							
81–100	1	1	8	18	13	3	44
101–120			1	4	6		11
121–140				2	1	3	6
141–160				2	6	8	16
161–180					2	2	4
181–200	1				3		4
200+	4	2			2	1	9
Total	6	4	9	26	39	17	101

Concentration of Data

Site Classification

Site description in the Alberta study is based on physiography and was classified according to moisture regimes as described in Part I and summarized in Table 2.

Kabzems, to ensure an adequate field sample and plot distribution, recognized differences in soil texture, drainage, present stand and productivity. His empirical yield tables, however, were prepared by three site quality groups. Plonski's (Ontario) tables refer to normal yields and site class subdivision is arbitrary, with the three site classes based on distribution of stands by height in even-aged black spruce. The Ontario tables by Bedell, MacLean and Brown are empirical, and four physiographic sites, B, D, G and K are recognized according to the nature of the organic and mineral horizons of the soil profile. The characteristics of these sites were found to be reflected in the corresponding dominant height/age relationships.

Both physiographic classification and arbitrary growth index have been used in preparing these tables and both are involved in the comparisons which follow. Relationships of the sites as classified in the different yield studies are shown in Table 12.

Table 12

PHYSIOGRAPHIC SITE COMPARISON

Moisture Regime	Alberta Site Type	Saskatchewan	Ontario (Plonski)	Ontario (Bedell) Site Type
2	Mesic Upland	Upland	1	
3	" "			
4	Upland Transition		2	B
5	Upland Transition			
6	Bog Border	Bog Border	3	D
7	Shallow Bog	Swamp		G
8	Deep Bog			K

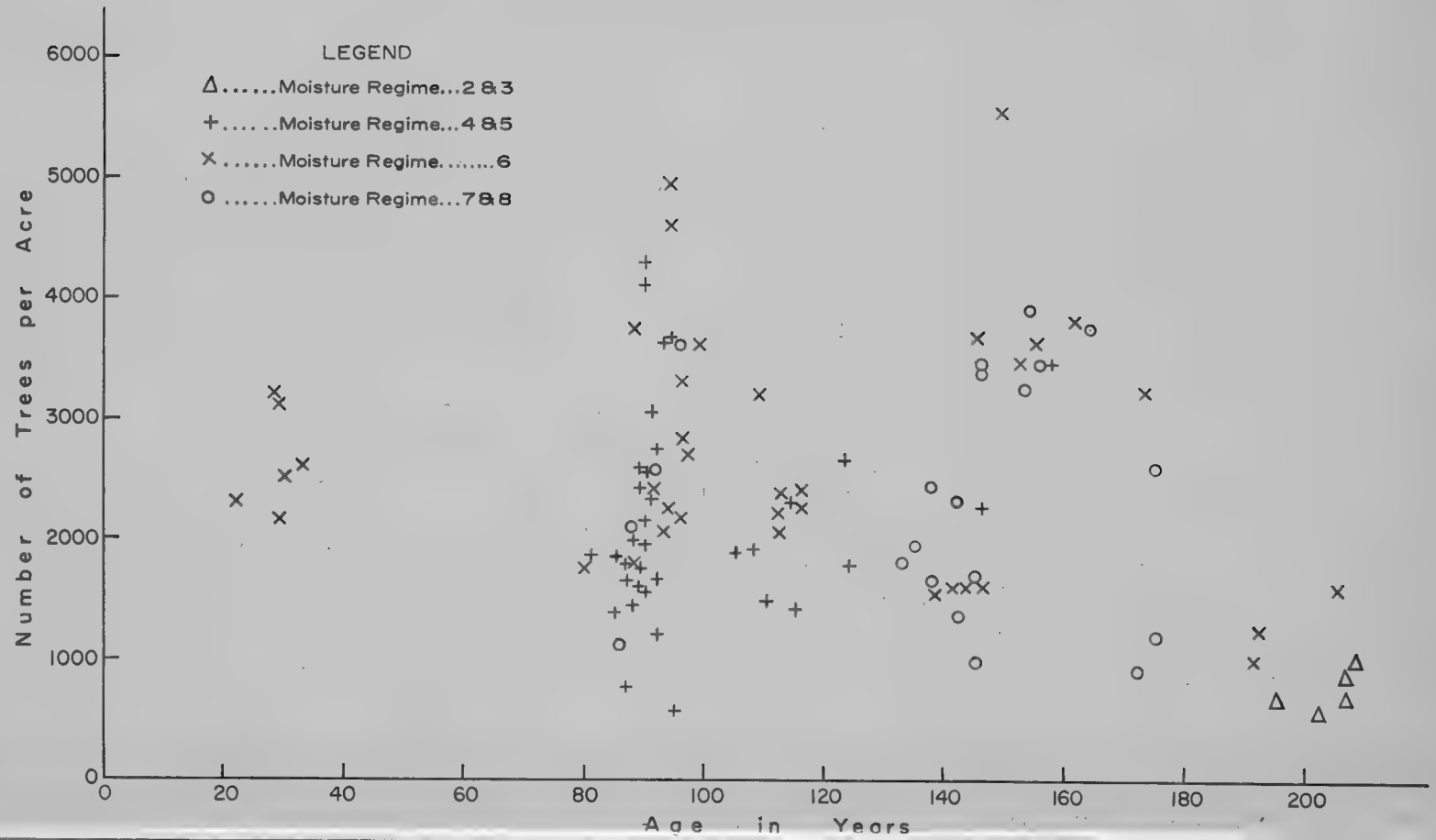
Growth Criteria

In the following presentation the comparability of the existing yield tables to the Alberta data will be assessed by comparisons of growth curve level and shape. Curve level is an expression of the relationship between site condition and the productive capacity of the species concerned. It may also be affected by stocking density and by stem distribution. Further, it may be expected to vary between the different study regions, depending upon the suitability of the species to the particular regional conditions. Curve shape is mainly a function of growth trend of the species with age. However, it may be markedly affected by density and stem distribution. Since insufficient data are available from Alberta to establish curve level for the main sites, the greatest emphasis in comparing the Alberta data with those from other tables will be placed on curve shape.

At this point it is as well to note the one outstanding feature of the Alberta data, that is, the variable nature of stocking, and in particular the large number of stems per acre which survive to advanced ages.

In Figure 20 the individual plot data are presented for the number of stems/age relationship, different symbols being used for the main physiographic sites.

FIGURE 20. NUMBERS OF STEMS BY SITE CLASSES



The wide degree of scatter is at once obvious, stocking at any age varying by about 3,000 stems. The unusually high number of stems at advanced ages should be noted. It is inevitable that this will affect the following productivity comparisons with reference to both age and site.

After consideration of a number of growth relationships, the following were selected for comparison of curve shape and curve level.

(1) Dominant height/age
(2) Basal area/age
(3) Average diameter/average dominant height
(4) Total volume/average dominant height
(5) Merchantable volume/average dominant height.

Deficiences in the range and concentration of the Alberta data, already described, have made it possible to illustrate only average Alberta site conditions. Therefore, comparative values have been interpolated between site and age classes from the other tables and are presented for the dominant Alberta site, moisture regime 6.

Growth Comparisons

The most useful comparisons between the different studies are those of dominant height and basal area in relation to age. The curves are presented for 100 years index age.

Height

The height/age relationships presented in Figure 21 were established by interpolation from the yield tables at the average value, moisture regime 6, for the Alberta data using an index age of 100. In the Saskatchewan tables where height/age curves vary in shape with site, interpolation was from the medium II site curve. There is little variation in the shape of the height curves. The Alberta curve is, however, almost identical to that of Plonski's. Since dominant height is an expression of age, site and density, this provides a valuable guide to further comparison.

Basal Area

Basal area is first compared in Table 13, and the high levels of the Alberta data are noteworthy. The basal area curves in Figure 22 again show a marked similarity between the Alberta (moisture regime 6) and Ontario (Plonski) average data. It is suggested that the large number of stems surviving in the older age classes prevents the Alberta curve of basal area from falling off. Only the Plonski curve for normal stocking exhibits a similar tendency. The other studies indicate an earlier culmination of growth than in Alberta stands and an earlier decline in the stand as openings develop and break-up commences around 110–120 years. The Alberta stands, which still have a density of 3,000 stems at 100 to 120 years, cannot be said to have begun to break up. Hence, they maintain a high basal area per acre at this age.

Volume

On the basis of similarities in curve shape and level, the Plonski data were used with the Alberta data for the comparisons of volume relationships shown in Figures 23, 24 and 25.

The diameter and volume relationship with dominant height is employed, since it was found to be impracticable to construct curves related to age alone, owing to the stand density effect. The Plonski values for diameter and merchantable volume were therefore interpolated from the tables for the age and site index values corresponding to the Alberta average curve. Total volume for the average site was compared at 100 years index age. A 3.5-inch lower diameter limit was used to determine merchantable cubic foot volume.

FIGURE 21. DOMINANT HEIGHT / AGE

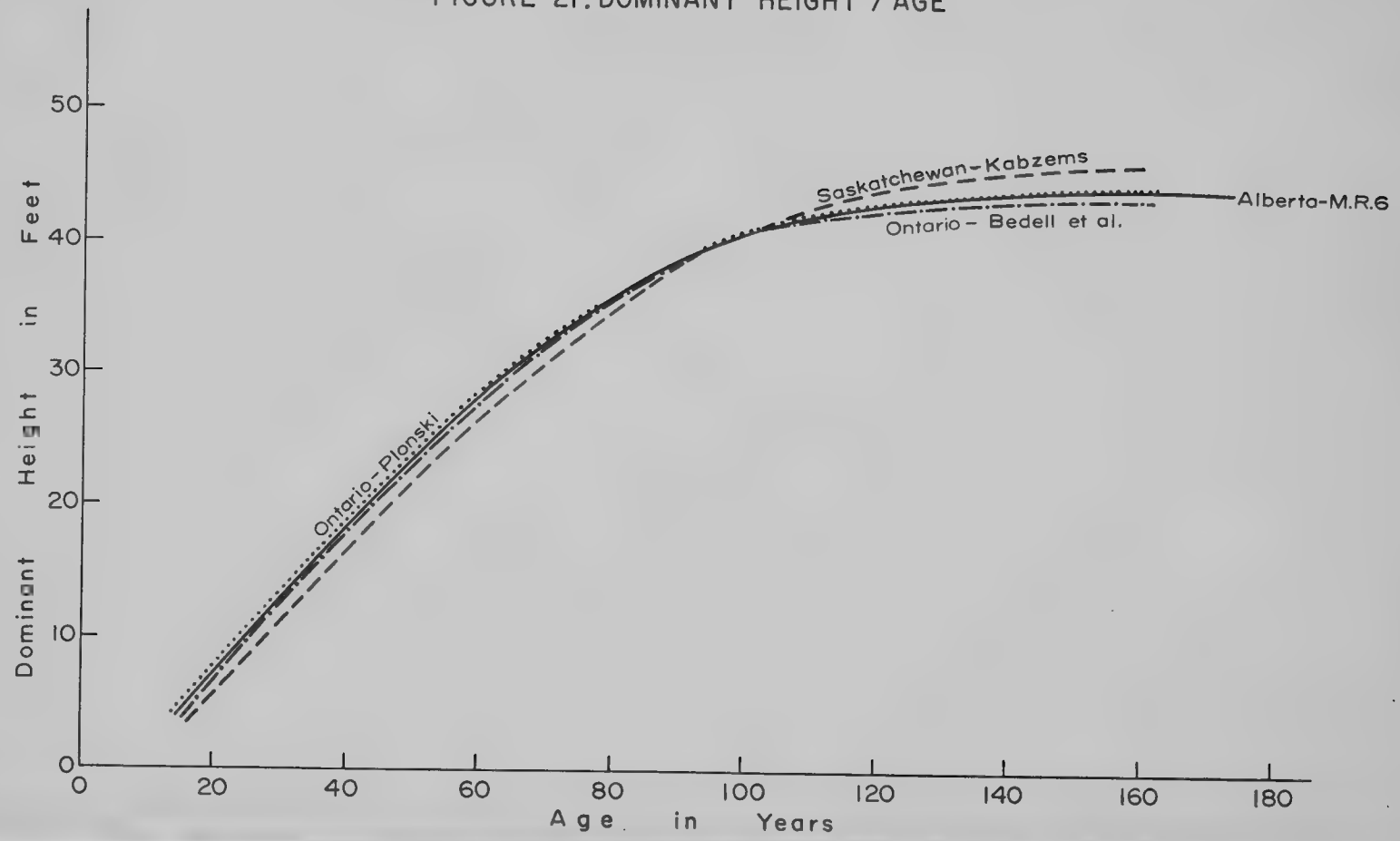


Table 13

COMPARISON OF BASAL AREA PER ACRE AT 100 YEARS OF AGE

Alberta				Ontario Bedell et al.		Ontario Plonski		Saskatchewan	
Site	Basal Area at 100 Years			Site	Basal Area at 100 Years	Site	Basal Area at 100 Years	Site	Basal Area at 100 Years
	Min.	*Ave.*	*Max.*		*Average*		*Average*		*Average*
Mesic Upland MR 2 + 3	160	180	200			Site 1	170	Site I Good	169
Upland Transition	160	200	240	B	153	Site 2	157	Site II Medium	163
Bog and Bog Border	110	140	180	D G	158 143	Site 3	137	Site III Poor	137
Deep Bog (unmerchantable)	Less than 100			K	104				

FIGURE 22. BASAL AREA / AGE FOR AVERAGE SITE

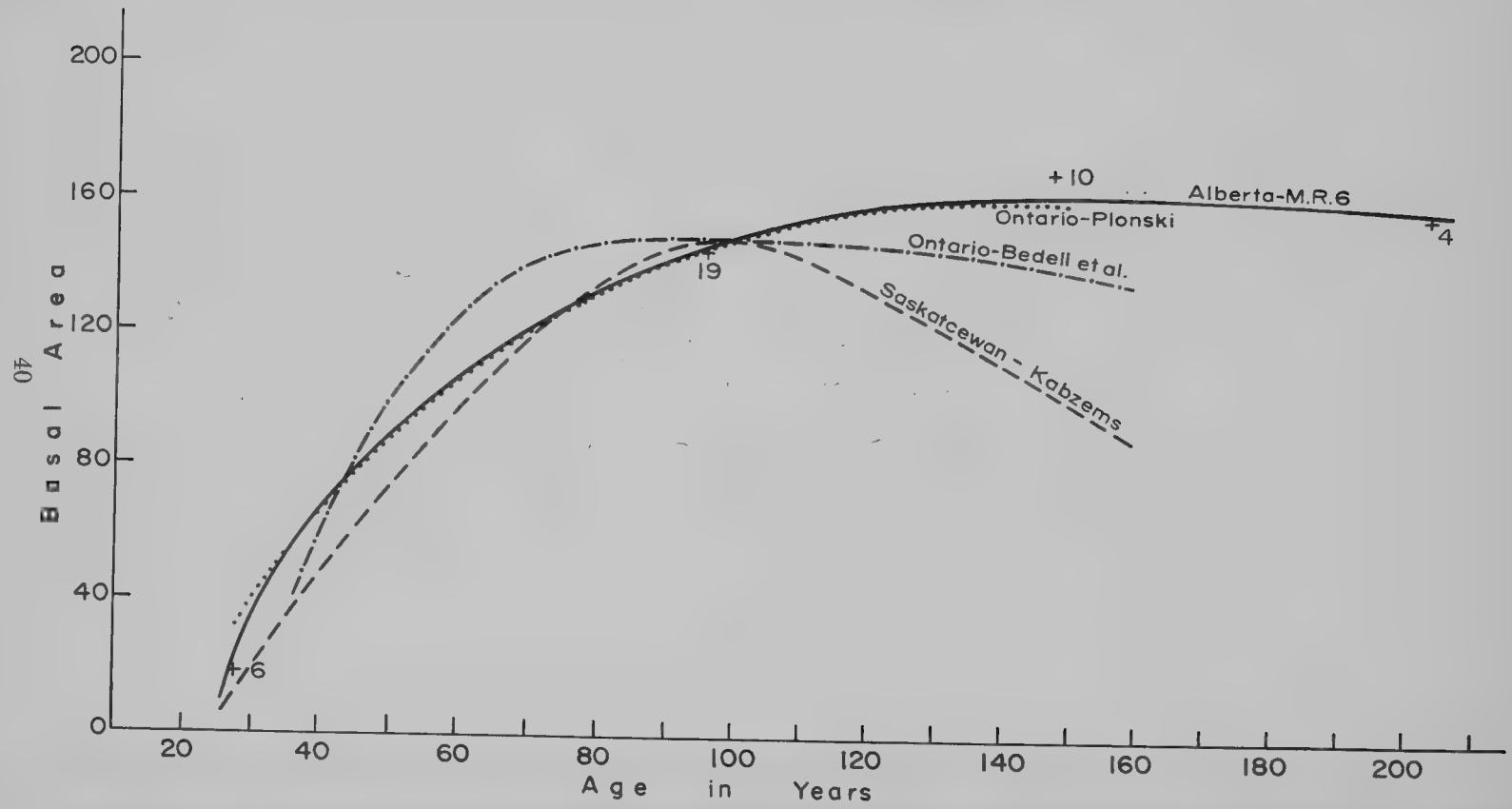


FIGURE 23. AVERAGE DIAMETER / AVERAGE DOMINANT HEIGHT
FOR CORRESPONDING AGE & SITE INDEX

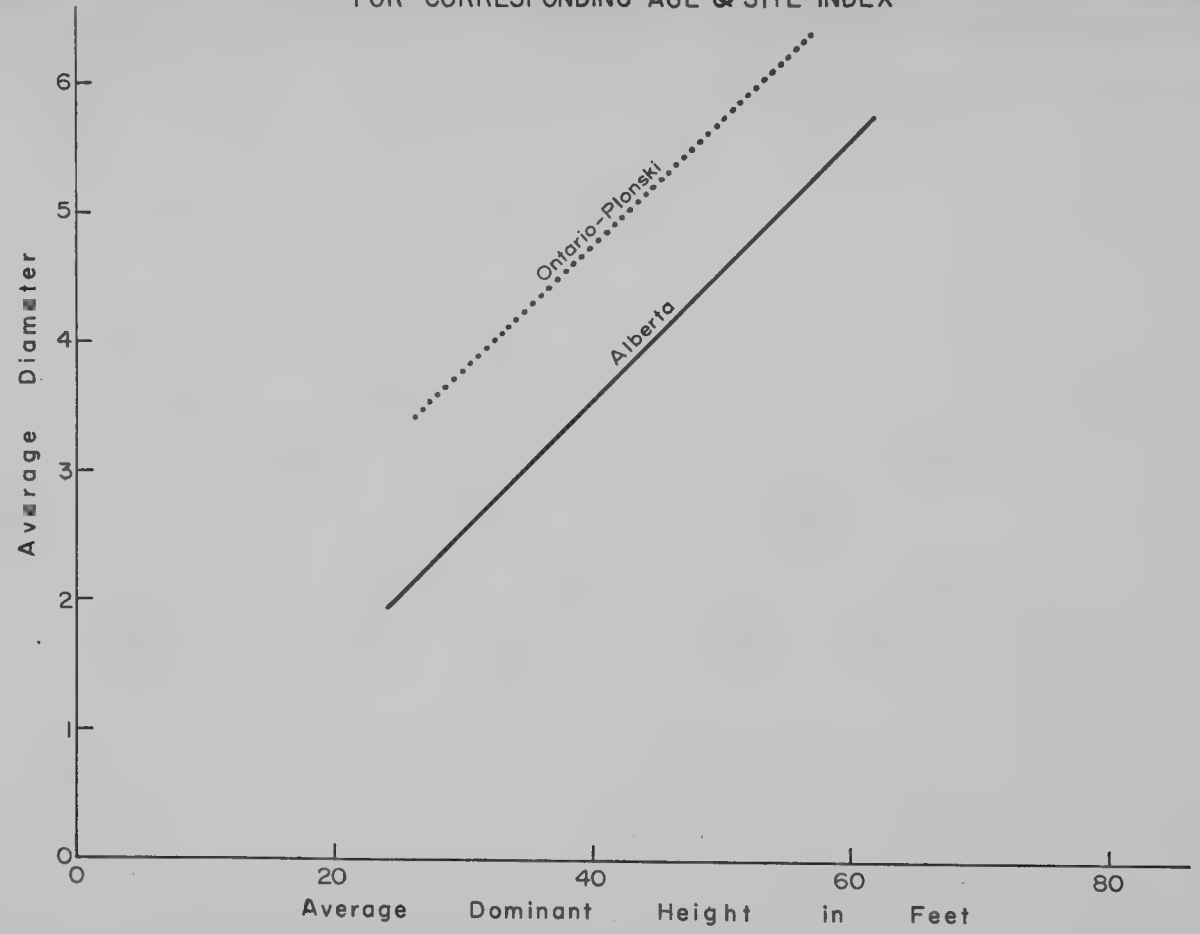


FIGURE 24. TOTAL VOLUME / ACRE – AVERAGE DOMINANT HEIGHT

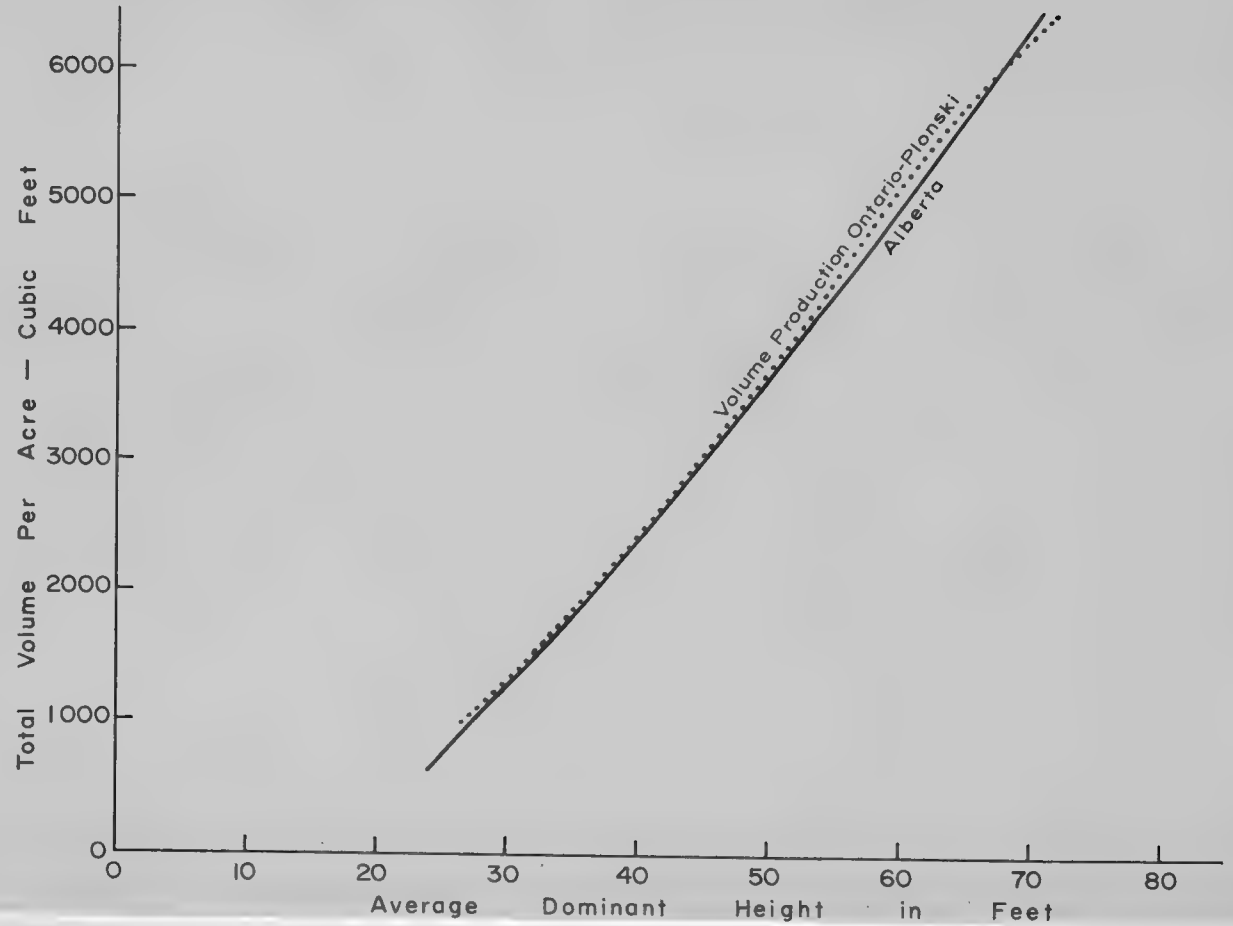


FIGURE 25. MERCHANTABLE VOLUME – AVERAGE DOMINANT HEIGHT

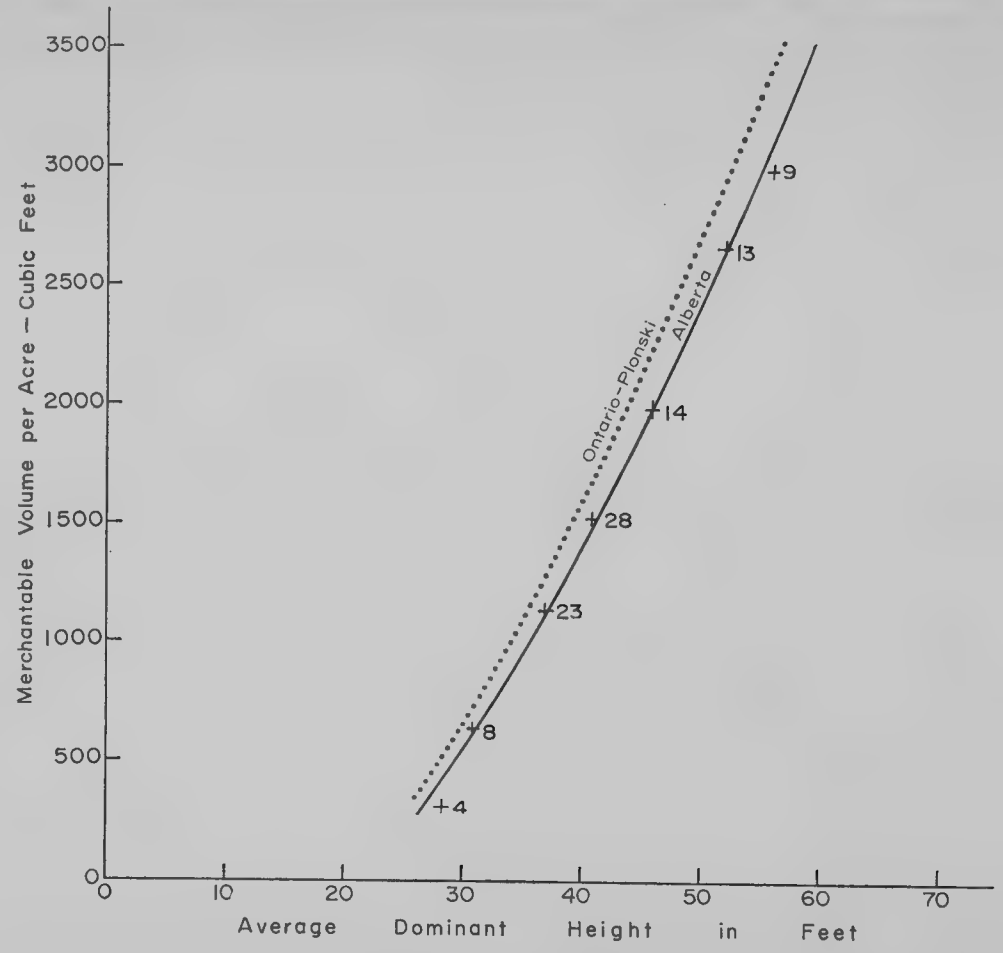
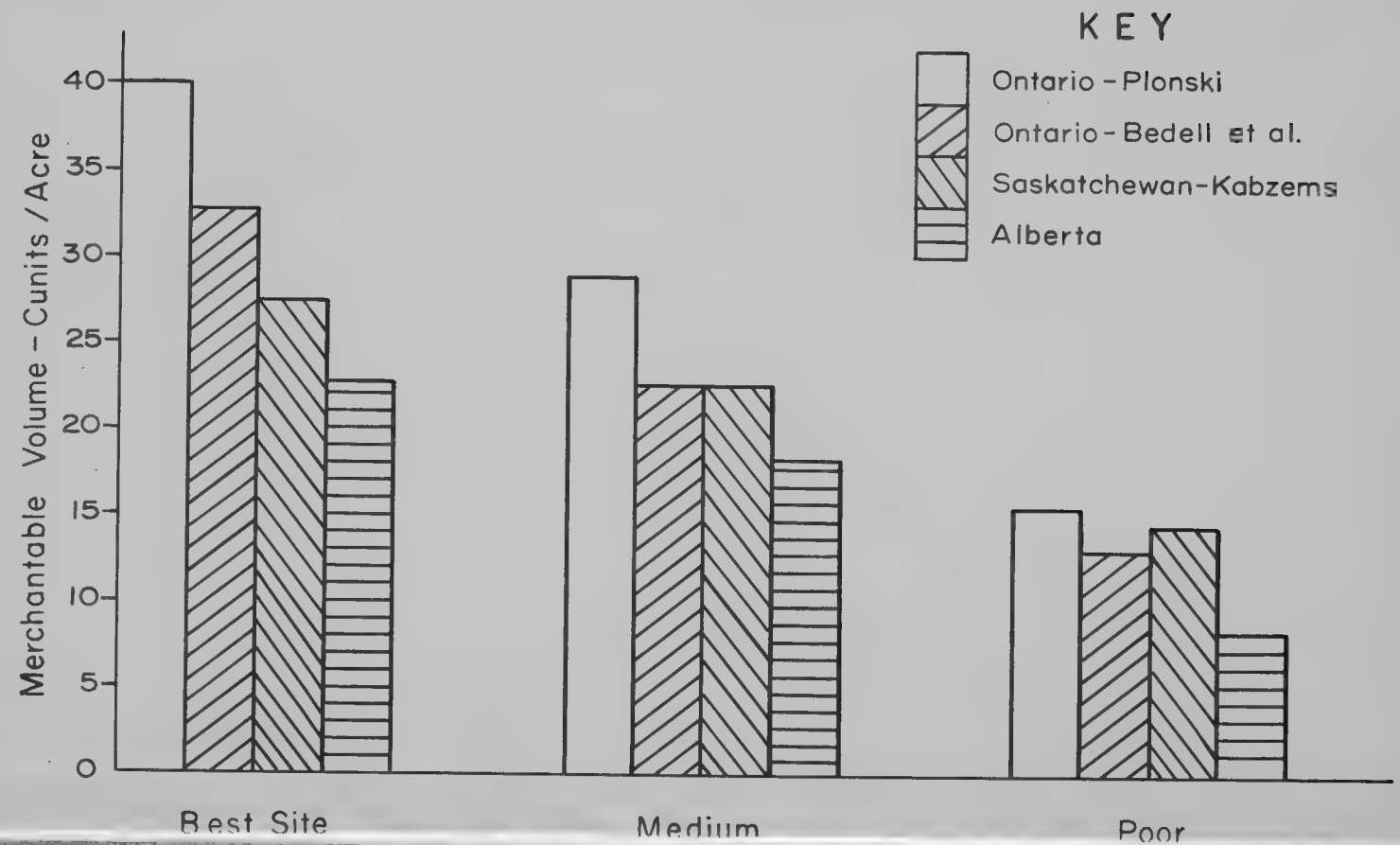


FIGURE 26. PRODUCTIVITY COMPARISONS, AGE 120 YEARS



A further comparison of merchantable volume is presented in histogram form in Figure 26. The productivity trend with site is outstanding in all four studies. Variation among the medium sites of the various regions is relatively small but it is noticeable that yields from Plonski's normal stands are consistently highest.

The curves of diameter and volume prepared for the other studies differed markedly from one another in shape because of differences in preparation bases and in the represented stand growth characteristics. The Alberta curves do not conform in shape to those of Kabzems and Bedell *et al.*, but are constantly similar to Plonski's Ontario values.

Alberta Yield Tables

The favourable comparisons thus presented have led to the acceptance of the shape and dispersion of the families of curves developed by Plonski as suitable for the Alberta tables at selected site levels.

The following adaptation was carried out. The Alberta data were first grouped into three 10-foot site index classes; (1) 35′, (2) 45′, and (3) 55′, at 100 years. These were selected arbitrarily on consideration of the range and mean of the height index values. The shapes of the Plonski height curves for corresponding site indices were fitted at these height index values.

Secondly, the average basal area for each Alberta site index class was plotted and the basal area/age curves were generated by interpolation from Plonski's yield table, giving harmonized basal area/age curves for the three site classes. Thirdly, the curves for total and merchantable cubic foot volume were similarly prepared, and finally the curve values were read from Figures 27, 28, 29 and 30, and are presented in Tables 14, 15 and 16.

Table 14

YIELD OF BLACK SPRUCE IN ALBERTA FOOTHILLS
Site 1—55 Ft. at 100 Years

Age in Years	Dominant Height in Feet	Basal Area Sq. Ft.	Total Volume Cu. Ft.	Merchantable Volume Cu. Ft.
		per acre		
20	12.5	79.0		
25	16.6	107.5		
30	20.7	127.0	750	
35	24.5	143.0	1025	
40	28.4	155.5	1300	
45	31.7	163.5	1575	320
50	34.7	169.0	1840	500
55	37.5	174.0	2100	700
60	40.0	178.0	2360	925
65	42.3	181.5	2600	1160
70	44.5	184.0	2820	1400
75	46.5	186.0	3020	1650
80	48.6	188.0	3200	1875
85	50.5	190.0	3375	2100
90	52.2	191.5	3540	2315
95	53.7	192.5	3690	2525
100	55.0	193.5	3830	2700
105	56.3	194.5	3950	2880
110	57.4	195.0	4050	3025
115	58.5	196.0	4150	3170
120	59.5	196.5	4225	3280
125	60.4	197.0	4285	3390
130	61.1	197.5	4335	3465
135	61.8	198.0	4370	3530
140	62.5	198.0	4400	3575
145	63.0	198.0	4415	3615
150	63.4	198.0	4420	3640
155	63.6	198.0	4425	3660
160	63.7	198.0	4425	3665

FIGURE 27. DOMINANT HEIGHT / AGE BY SITE CLASSES

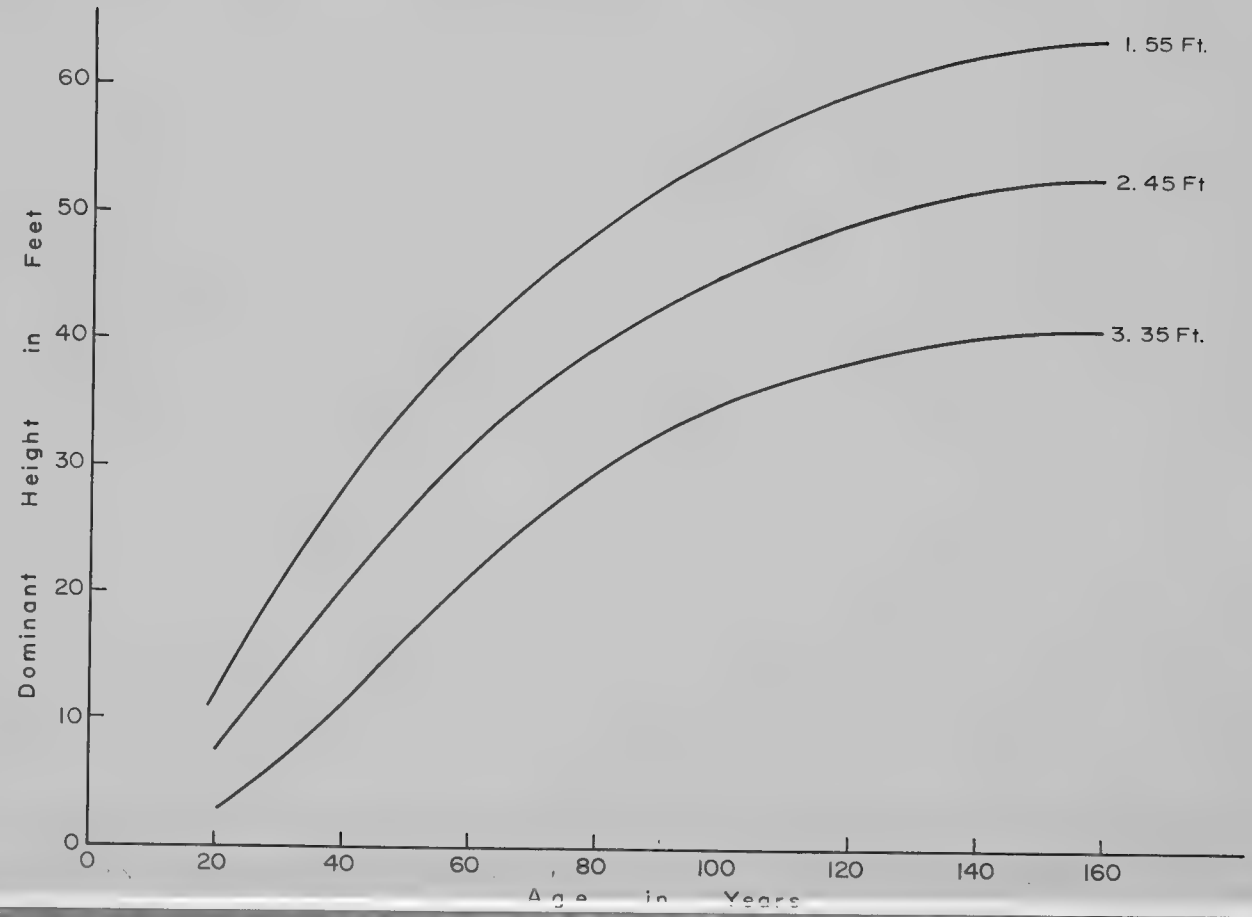


FIGURE 28. BASAL AREA / AGE BY SITE CLASSES

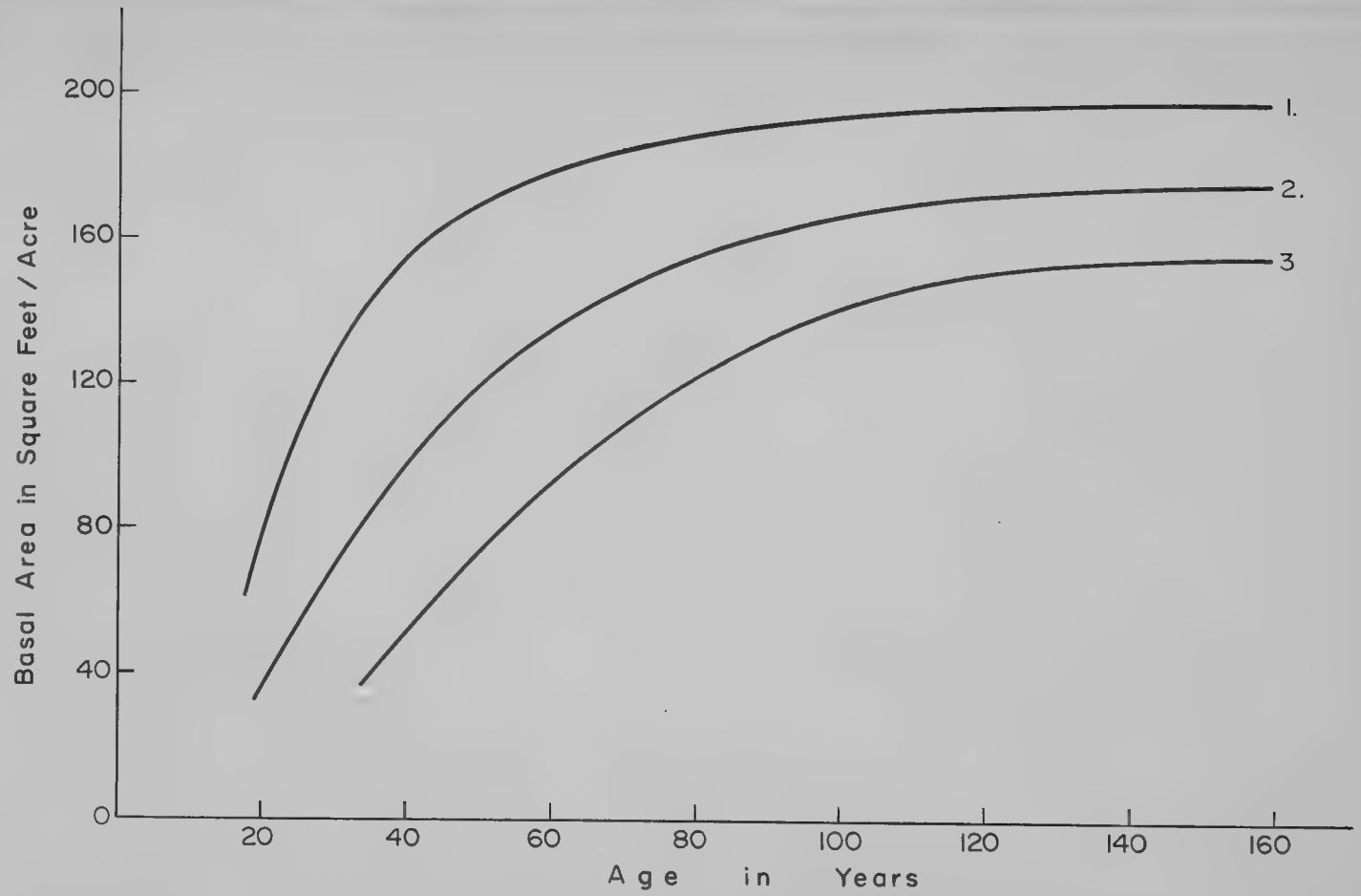


FIGURE 29. TOTAL VOLUME / ACRE BY SITE CLASSES

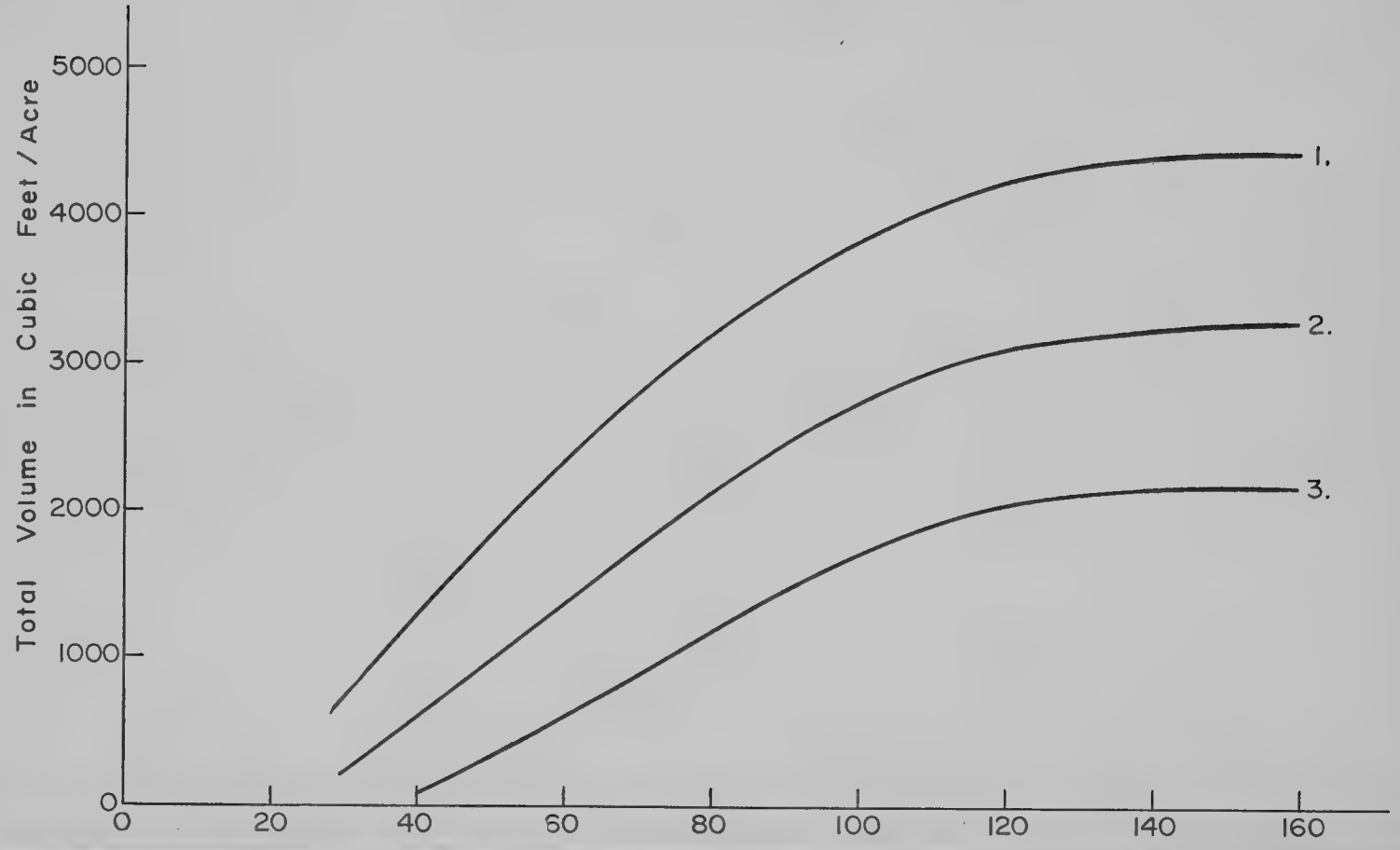


FIGURE 30. MERCHANTABLE VOLUME / AGE BY SITE CLASSES

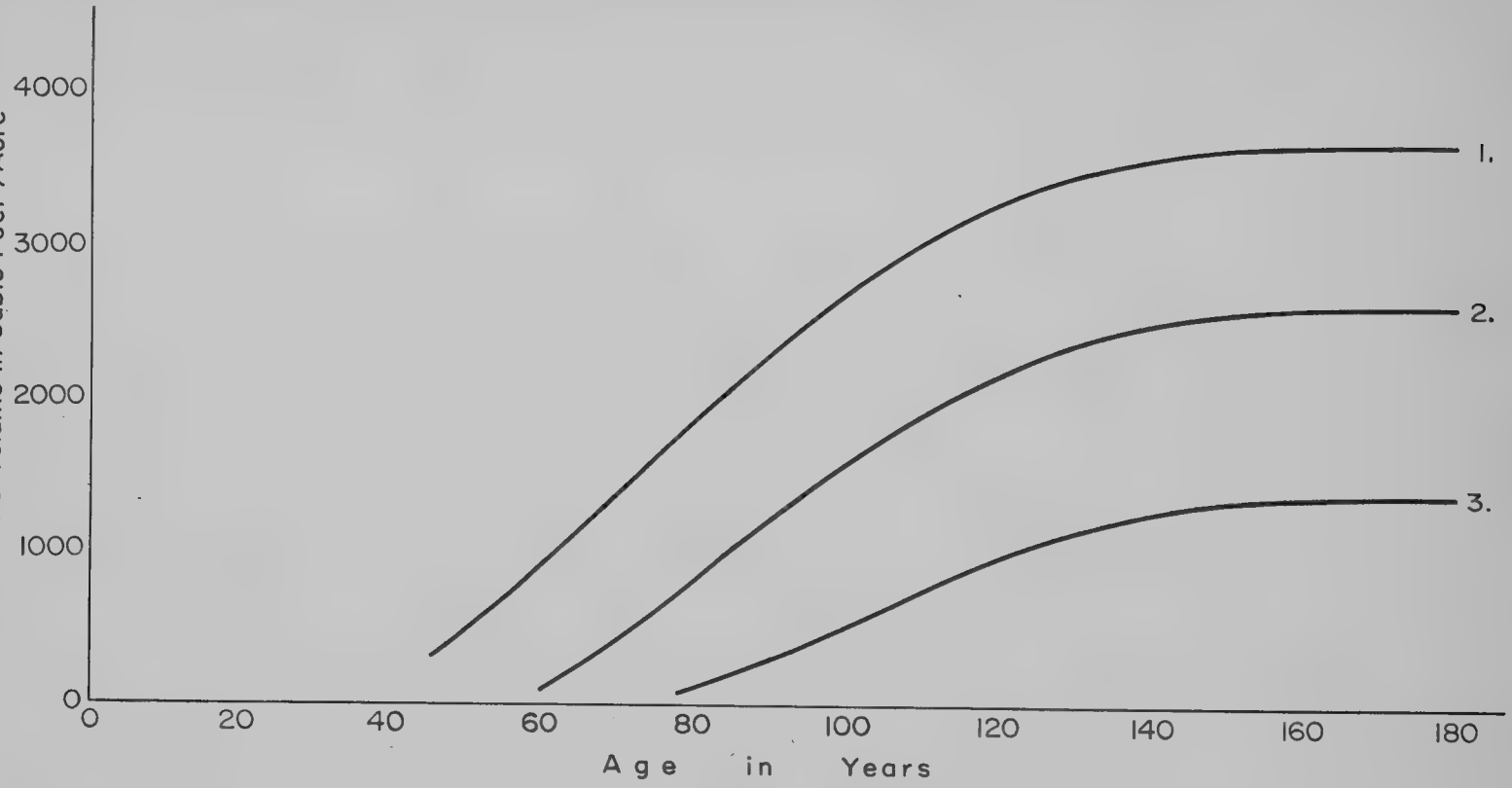


Table 15

YIELD OF BLACK SPRUCE IN ALBERTA FOOTHILLS

Site 2—45 Ft. at 100 Years

Age in Years	Dominant Height in Feet	Basal Area Sq. Ft.	Total Volume Cu. Ft.	Merchantable Volume Cu. Ft.
		per acre		
20	8.0	36.5		
25	10.9	53.5		
30	14.1	70.0	240	
35	17.3	84.5	425	
40	20.4	97.5	620	
45	23.5	109.5	800	
50	26.3	119.5	1000	
55	29.0	127.5	1185	
60	31.4	135.0	1375	120
65	33.7	141.0	1575	275
70	35.8	146.5	1760	450
75	37.6	151.5	1950	630
80	39.5	155.5	2125	840
85	41.0	159.0	2300	1040
90	42.5	162.0	2460	1225
95	43.9	164.0	2600	1415
100	45.0	166.0	2735	1585
105	46.3	168.0	2850	1750
110	47.4	169.5	2950	1900
115	48.4	171.0	3025	2040
120	49.3	171.5	3090	2165
125	50.1	172.5	3140	2270
130	50.9	173.0	3180	2360
135	51.6	173.5	3215	2440
140	52.1	174.0	3240	2490
145	52.5	174.5	3260	2535
150	52.7	175.0	3275	2565
155	52.8	175.0	3285	2585
160	52.8	175.5	3290	2600

Table 16

YIELD OF BLACK SPRUCE IN ALBERTA FOOTHILLS

Site 3—35 Ft. at 100 Years

Age in Years	Dominant Height in Feet	Basal Area Sq. Ft.	Total Volume Cu. Ft.	Merchantable Volume Cu. Ft.
		per acre		
20	3.0			
25	4.8			
30	6.9			
35	9.1	40.0		
40	11.4	52.0		
45	14.0	63.5	100	
50	16.5	74.0	340	
55	19.0	84.0	475	
60	21.4	93.0	615	
65	23.8	101.5	765	
70	25.9	109.0	910	
75	27.9	115.5	1050	
80	29.6	112.0	1190	120
85	31.3	128.0	1340	200
90	32.7	133.0	1475	300
95	34.0	137.5	1600	410
100	35.0	141.0	1720	525
105	36.0	144.0	1830	650
110	36.9	147.0	1915	765
115	37.6	149.0	1990	875
120	38.3	150.5	2050	975
125	38.9	152.0	2100	1065
130	39.6	153.0	2125	1140
135	40.0	153.5	2150	1200
140	40.4	154.0	2165	1260
145	40.7	154.5	2170	1300
150	40.9	155.0	2175	1340
155	41.0	155.0	2175	1360
160	41.0	155.5	2175	1375

Table 17

COMPARISON OF MOISTURE REGIME, SITE GROUPS AND INDEX HEIGHT SITE CLASSES

Site	Moisture Regime	Average Dominant Height	Site	Index Height
Mesic Upland	MR 2 — MR 3	56 ft.	Site 1 —	55 ft.
Upland Transition	MR 5 —	50 ft.		
	MR 4 —	46 ft.	Site 2 —	45 ft.
Bog Border	MR 6 —	40 ft.		
Bog, Shallow	MR 7 —	32 ft.	Site 3 —	35 ft.

Re-examination of the Alberta height/age data showed that the three arbitrary site classes most closely correspond to the Upland, Transition and Bog physiographic sites respectively. Thus, either index height or physiographic site may be adopted in field determination of site class. The appropriate table may then be used for yield prediction. As a cross-check, the plot values for basal area and volume were interpolated in the yield tables and these were compared with the actual plot data. For basal area, total volume and merchantable volume, the differences were within 5, 9.5 and 17.3 per cent respectively. Variability in volume values is undoubtedly due to the great range in plot densities.

Because of the extreme variability in stocking of black spruce stands in Alberta and the variations in yield, application of the tables is to some extent limited to well-stocked or average-stocked stands in the three broad site groups. For other density levels, the data are unreliable. It is recommended that the tables be applied only to relatively large areas including a wide range of sites rather than to single stands.

These tables are considered suitable only for interim use. In the light of the discussion of growth habits, future yield table construction for black spruce stands in Alberta may require the use of a means of relating stocking classes to yield. A stocking classification based on site might be used. When this added variable is taken into consideration, variations in yield with site or age class could be minimized.

NOMENCLATURE

Common Name	Symbol	Botanical Name
Black spruce	bS	*Picea mariana* (Mill.) BSP.
White spruce	wS	*Picea glauca* (Moench) Voss
Engelmann spruce	eS	*Picea engelmannii* Parry
Lodgepole pine	lP	*Pinus contorta* Dougl. var. *latifolia* Engelm.
Tamarack (Larch)	tL	*Larix laricina* (Du Roi) K. Koch
Alpine fir	aF	*Abies lasiocarpa* (Hook) Nutt.
Balsam poplar	bP	*Populus balsamifera* L.
Aspen	tA	*Populus tremuloides* Michx.
Birch	wB	*Betula papyrifera* Marsh.
Bog mosses		*Camptothecium nitens* *Aulacomnium palustre* *Sphagnum* spp.
Feather mosses		*Hylocomium splendens* *Pleurozium schreberi* *Hypnum crista-castrensis*

REFERENCES

Baldwin, H. I. 1931. The period of height growth in some northeastern conifers. Ecol. 12:665–689, illus.

Bannan, M. W. 1940. The root system of northern Ontario conifers growing in sand. Amer. Jour. Bot. 27:108–114, illus.

Bedell, G. H. D., D. W. MacLean and W. G. E. Brown. 1955. Preliminary empirical yield tables for black spruce. Forest Sections B.4 and B.9, Ontario and Quebec. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div. S. and M. 55–2.

Beeftink, H. H. 1951. Some observations on tamarack or eastern larch. For. Chron. 27:38–39.

Bellefeuille, R. 1935. La reproduction des peuplements d'épinette noire dans les forêts du nord de Québec. For. Chron. 11:323–340, illus.

Berry, A. B. and J. L. Farrar. 1956. Reproduction and growth in cut-over black spruce swamps at the Petawawa Forest Experiment Station. Canada, Dept. of Northern Affairs and National Resources. For. Br., For. Res. Div., Tech. Note No. 42.

Blyth, A. W. 1952. White spruce standard volume tables for the Boreal and Sub-alpine Regions of Alberta. Canada, Dept. of Resources and Development. For. Br., Silv. Leaf. No. 60.

————1955. Standard volume tables for lodgepole pine in Alberta. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 9.

————1955. Yield of even-aged fully stocked spruce-poplar stands in northern Alberta. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 18.

Brown, R. M., and S. R. Gevorkiantz. 1934. Volume, yield and stand tables for tree species in the Lake States. Table No. 139. University of Minnesota. Tech. Bull. No. 39.

Candy, R. H. 1951. Reproduction on cut-over and burned-over land in Canada. Can. Dept. of Resources and Development, For. Br., Bull. No. 89.

Chai, T. S. and Hansen, H. L. 1952. Characteristics of black spruce seed from cones of different ages. Univ. Minn. Sch. For., Minn. For. Notes 2:2 pp.

Cunningham, G. C. 1958. Forest flora of Canada. Canada, Dept. of Northern Affairs and National Resources, For. Br., Bull. No. 121. 144 pp.

Gates, F. C. 1938. Layering in black spruce. Amer. Midland Nat. 19:589–594.

Hills, G. A. 1952. The classification and evaluation of site for forestry. Ontario, Department of Lands and Forests. Div. of Res. Res. Rept. No. 24.

HORTON, K. W. 1956. The ecology of lodgepole pine in Alberta and its role in forest succession. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 45.

HEINSELMAN, M. L. 1957. Silvical characteristics of black spruce. U.S. Dept. of Agric., For. Serv., Lake States For. Expt. Sta. Station Paper No. 45.

JOHNSON, H. J. 1956. Some aspects of black spruce reproduction in the central Boreal Forest Region of Manitoba. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., S. and M. 56–3.

KABZEMS, A. 1953. The growth and yield of black spruce in Saskatchewan. Sask. Dept. Natural Resources, For. Br., Bull. No. 1, 52 pp., illus.

KENETY, W. H. 1917. Reproduction of black spruce (*Picea mariana*). Jour. For. 15:446–448.

LEBARRON, R. K. 1948. Silvicultural management of black spruce in Minnesota. U.S. Dept. of Agric., Cir. 791, 60 pp., illus.

LEBLANC, J. H. 1954. A mode of vegetative reproduction in black spruce. Canadian Pulp and Paper Assoc., Woodlands Section, Index No. 1475 (F.2).

LINTEAU, A. 1957. Black spruce reproduction on disturbed soil conditions. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 54.

MACLEAN, D. W., and G. H. D. BEDELL. 1955. Northern Clay Belt growth and yield survey. Canada, Dept. of Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 20.

MILLAR, J. B. 1936. The silvicultural characteristics of black spruce in the Clay Belt of Northern Ontario. Faculty of Forestry. University of Toronto. Unpub. Thesis (M. Sc. F.).

MOSS, E. H. 1955. The vegetation of Alberta. Bot. Rev. 21(9):493–567.

PLACE, I. C. M. 1950. Origin of reproduction on black spruce swamps. Canada, Dept. of Resources and Development. For. Br., For. Res. Div., Silv. Leaf. No. 38.

PLONSKI, W. L. 1956. Normal yield tables for black spruce, jack pine, aspen and white birch. Ontario Dept. of Lands and Forests, Division of Timber Management, Report No. 24.

RAUP, H. M. 1945. Forests and gardens along the Alaska Highway. Geog. Rev. 35:22–48, illus.

ROE, E. I. 1949. Sphagnum moss retards black spruce regeneration. U.S. Dept. of Agric., For. Serv., Lake States For. Expt. Sta. Tech. Note 321, 1 p.

ROWE, J. S. 1955. Factors influencing white spruce reproduction in Manitoba and Saskatchewan. Canada, Dept. Northern Affairs and National Resources, For. Br., For. Res. Div., Tech. Note No. 3.

————1959. Forest regions of Canada. Canada, Dept. Northern Affairs and National Resources, For. Br., Bull. No. 123.

WALDRON, R. M. 1957. The amount and viability of seed from cones of different ages—black spruce. Canada, Dept. Forestry, For. Res. Br., unpub. report, 7 pp.

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DUE CAM DEC 18 '81	NOV 29 RETURN
DEC 18 RETURN	DUE CAM OCT 23 '90
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